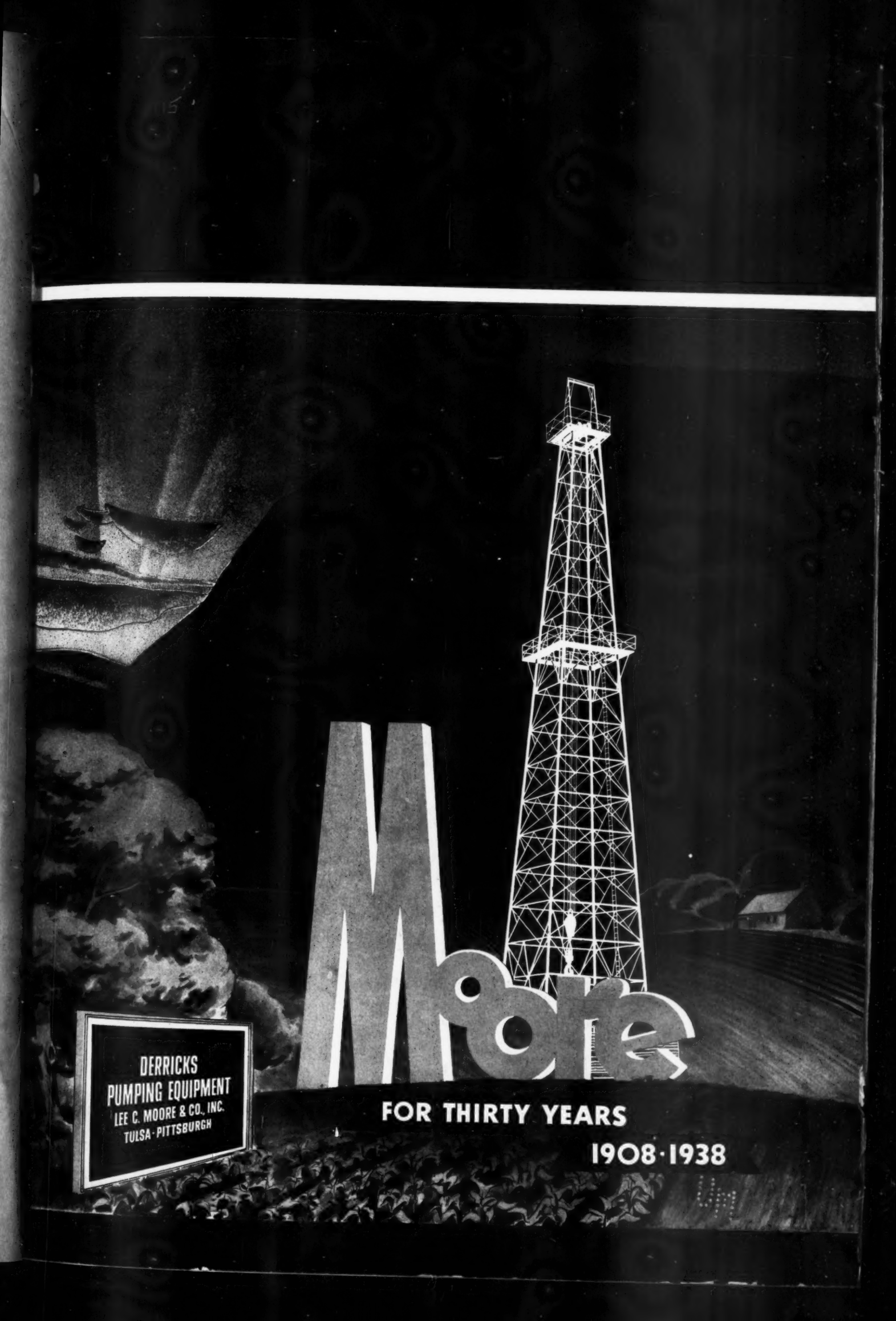
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MEETINGS

National Petroleum Association, Department of Fire and Accident Prevention, Semi-Annual Meeting —October 26, Olean, New York.

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Mid-Continent Oil and Gas Association, Texas Division—October 27, 28, and 29, San Antonio, Texas.

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Western Petroleum Refiners Association—October 28, Washington-Youree Hotel, Shreveport, Louisiana.

•

California Natural Gasoline Association — November 3, Richfield Building, Los Angeles, California.

•

American Association of Petroleum Geologists, Pacific Section —November 3 and 4, Los Angeles, California.

•

Mid-Continent Oil and Gas Association, Annual Meeting of Kansas-Oklahoma Division — November 4, Tulsa, Oklahoma.

•

American Petroleum Institute, 19th Annual Meeting—November 14, 15, 16, 17, and 18, Stevens Hotel, Chicago, Illinois.

•

American Society of Mechanical Engineers—December 4, 5, 6, 7, 8, and 9, New York City.

•

Oil and Gas Association of Michigan, Annual Meeting — December 7, Mt. Pleasant, Michigan.

•

West-Central Texas Oil and Gas Association, Annual Meeting —December 10, Abilene, Texas.

•

Oil-World Exposition — April 24, 25, 26, 27, 28, and 29, 1939, Houston, Texas.

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Seventh Floor Allen Building Dallas, Texas Telephone: 2-4571

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The Course of Oil

By K. C. SCLATER

Development of Foreign Oil Fields Outside of the United States in recent years, large petroleum reserves have been discovered. So substantial, in fact, are some of these discoveries that they have stimulated foreign oil exploration and development and ushered in an era of activity never before witnessed in the history of foreign oil development.

When oil development operations are conducted on a vast and intensive scale in many remote parts of the world, innumerable new operating difficulties and problems are bound to arise. These have to be met, but the means to meet them may not always be at hand. A prevailing practice must be modified or a new method devised to meet the situation. An expedient may have to be resorted to—a practice not uncommon in foreign fields, where the proper material and equipment may be lacking and higher authority cannot be consulted at will.

In coping with the new conditions that confront them, those engaged in foreign fields usually develop a knack of overcoming difficult operating problems. At the same time, those same men recognize the necessity of keeping informed on the very latest operating methods and equipment, and that the longer they operate in foreign fields the greater this necessity becomes. Perhaps that is why men in foreign fields are alert to new methods and improvements in practice. They form the habit of weighing the advantages against the disadvantages before applying these improvements to their own operations; in this respect they seem to cultivate a mature deliberation.

It is not surprising then, that operations in some foreign fields are of a very high standard. The absence of highly competitive conditions is sometimes an important factor leading to the adoption of advanced methods. Certain of these fields have the advantage of being controlled and operated by one company, and so are explored and developed as a unit. Not only is the field produced as a unit, but refinery throughput is controlled to some extent by considerations of reservoir control. In other words, the efficiency and economy of producing operations and scientific reservoir control that will yield the greatest ultimate economic recovery are paramount considerations. They are not sacrificed to extraneous demands that too often intervene to impair economy and efficiency. Operated under such conditions, these unit-operated foreign fields become valuable and authoritative sources of information. Being produced under strict engineering control the results obtained are an index of what constitutes sound oil operations.

Those engaged in the industry at home cannot afford to overlook what is being accomplished in foreign fields any more than those engaged in foreign fields can afford to overlook what new practices are being developed elsewhere far from their own sphere of operations.

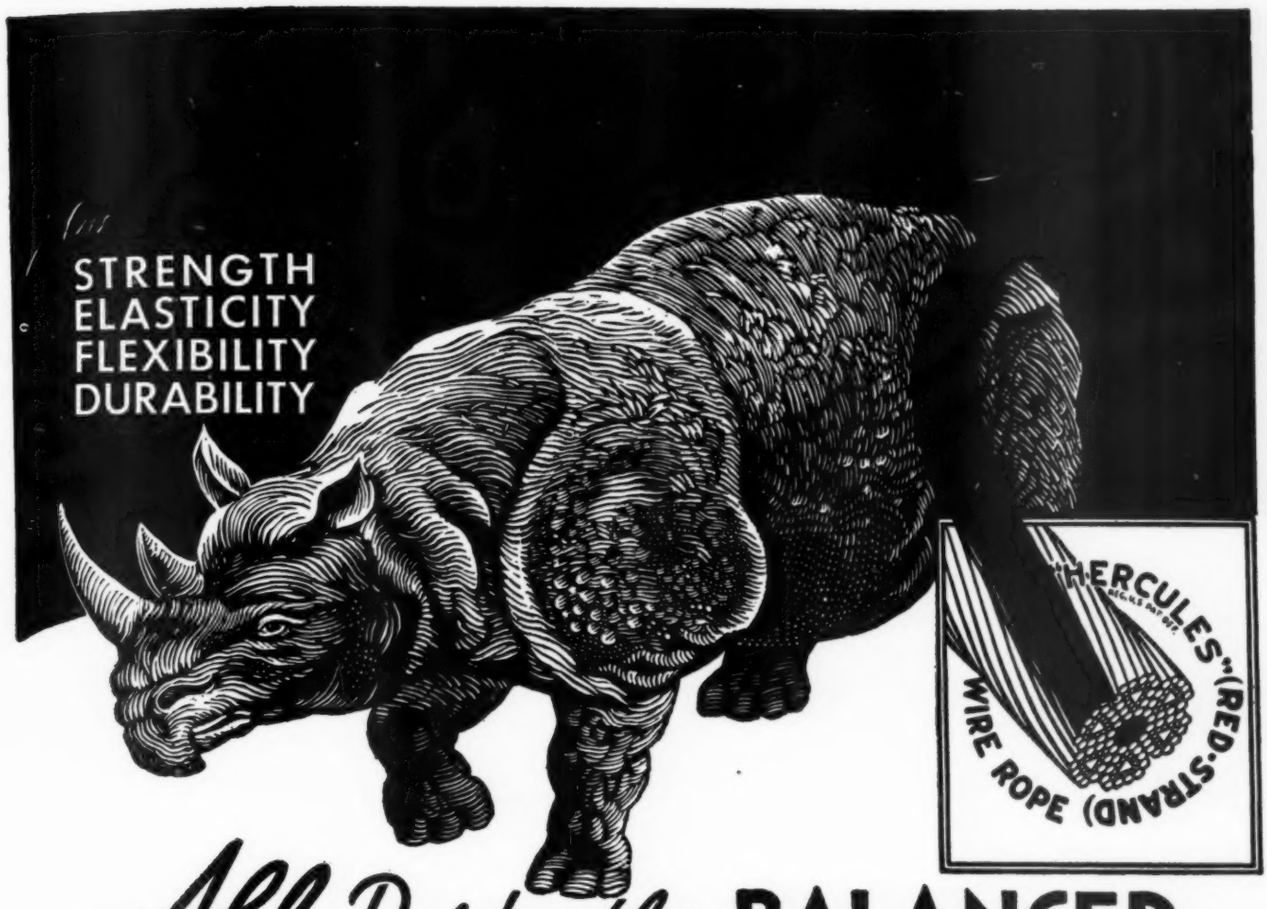
●

Petroleum in The Eastern Hemisphere Many of the most important producing areas in the world are in the Eastern Hemisphere, to which a special section of this issue is devoted. Some of these have been producing oil for many years, notably Roumania and Russia, and are still active centers of exploration and development.

Other areas, notably those of the Near East, which includes Iran, Iraq, and Arabia, contain fields having vast reserves that are of comparatively recent discovery. There, operations are particularly active. Modern methods and machinery are being employed. During the immediate years ahead this region is destined to be one of the most active in petroleum exploration and development. Operations conducted there, remote as the fields are from industrial centers of population, are likely to lead the world in the standard of efficiency attained and in the application of petroleum technological methods in general. Operations now being conducted are in charge of men well fitted by experience, training, and sound judgment to produce results.

Other important centers of oil activity in the Eastern Hemisphere are India, Burma, and the Netherlands East Indies. These areas are all noted for their oil operations, which include production, pipe-line transportation, and refining. Many of the operating methods in use are of interest; and it is surprising how they have kept pace with modern standard practice. Considering the conditions under which many of these fields have been developed, the results achieved are nothing short of remarkable.

All too little has been told of foreign oil exploration methods. There are always conditions encountered in foreign fields, climatic and otherwise, that enter to impair the efficiency of operations. Regardless of this fact, it can be said that today, the efficiency of oil operations in remote foreign fields are, on the whole, on a par with what is considered good practice in the most efficiently produced fields in the United States.



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General Decline In Crude Oil Prices

A general price reduction has been placed in effect by crude oil purchasers in Texas, Oklahoma, Kansas, Louisiana, Arkansas, New Mexico, and Illinois. Declines range from 12 to 20 cents per barrel. The Humble Oil and Refining Company posted the following price schedule for Texas and New Mexico and but for a few minor exceptions this schedule has been generally adopted:

East Texas field, $1.10 per bbl., a reduction of 15 cents a bbl.; West Central Texas, 71 cents to $1.13, according to gravity, a decline of 17 cents a bbl.; Gray County, Carson County, and Hutchinson County, down 12 cents a bbl.; East Central Texas, 78 cents to $1.12, a decline of 15 cents a bbl.; Tomball, Raccoon Bend (deep), and Satsuma, 95 cents to $1.41, a decline of 13 cents; West Texas and New Mexico, 53 cents to 95 cents, a decline of 13 cents; Gulf Coast, 79 cents to $1.28, a decline of 13 cents; Anahuac and Dickinson, 74 cents to $1.33, a decline of 13 cents; Mirando, 74 cents to $1.33, a decline of 14 to 18 cents; Refugio, 79 cents to $1.38, a decline of 13 cents; Salt Flat, Darst Creek, Hilbig, Carroll, Clark, and Zoboroski, down 13 cents; Van field, 93 cents, a decline of 17 cents; Pettus field, $1.29, a decline of 13 cents; Pecos County, 78 cents, a decline of 13 cents; Talco field, 55 cents, a decline of 18 cents; Flour Bluff, $1.27, a decline of 13 cents; Conroe, $1.27, a decline of 13 cents.

Humble does not post prices in North Texas but in that area the Panhandle Refining Company has announced a 25-cent decline for K.M.A. crude.

The Standard Oil Company of Louisiana was first to announce lower postings in Louisiana, followed by other companies. At Rodessa prices were reduced 20 cents a bbl. to $1.05. At Homer, Caddo, DeSoto-Sabine, Haynesville, Bunkie, and Cotton Valley new prices range from 73 cents to $1.05, a decline of 17 cents, and in South Louisiana the reduction was 16 cents, the new range being 74 cents to $1.20 a barrel.

El Dorado and Miller County, Arkansas, crude is now quoted at 73 cents to $1.05, a reduction of 17 cents; Buckner, Magnolia, and Village crude at 66 cents to 98 cents, a decline of 17 cents a bbl.; and Smackover crude, which was reduced recently, was cut only 2 cents to 73 cents.

In Oklahoma and Kansas the price reduction was 20 cents a bbl. to 60 cents to $1.10.

Illinois crude was reduced to $1.05 to $1.15 a barrel.

●

Interstate Compact Commission Meets

At its meeting in Tulsa, Oklahoma, the latter part of September the Interstate Oil Compact Commission adopted a resolution asking Congress to continue the compact for two more years, reëlected Col. E. O. Thompson of Texas chairman, and selected Fort Worth, Texas, as the place for the December meeting. The commission also authorized its fact-finding committee, appointed at the Colorado Springs meeting, to continue its study and to make a detailed report within 60 days. Judge E. R. Sloan, chairman of the Kansas Corporation Commission, is head of the committee. Representatives from Oklahoma, Texas, Colorado, New Mexico, Kansas, and Illinois, members of the compact, pledged their states to the support of all conservation measures.

California, Wyoming, Louisiana, Indiana, and Pennsylvania, non-members, were represented at the meeting by observers.

Lieut. Gov. Hiram M. Dow of New Mexico was reëlected vice-chairman. Arthur L. Walker, former member of the Oklahoma Corporation Commission, was appointed secretary-treasurer by Chairman Thompson.

●

France's Crude Imports Increase

France's imports of crude oil increased and imports of refined products decreased during the first six months of the year as compared with the first six months of 1937, according to a report from the office of the American Commercial Attache at Paris to the U. S. Department of Commerce.

Crude petroleum imports totaled 3,207,000 metric tons compared with 3,109,000 tons in 1937; imports of refined petroleum products totaled 613,000 tons compared with 784,000 tons for the first half of 1937.

●

Texas Commission Upheld In Space Ruling

The Third Court of Appeals at Austin, Texas, has affirmed a Texas Railroad Commission permit to R. M. Wood for the drilling of a well on a one-acre tract in Gregg County. This decision is of interest because the controversy provoked a general attack on the East Texas oil proration order.

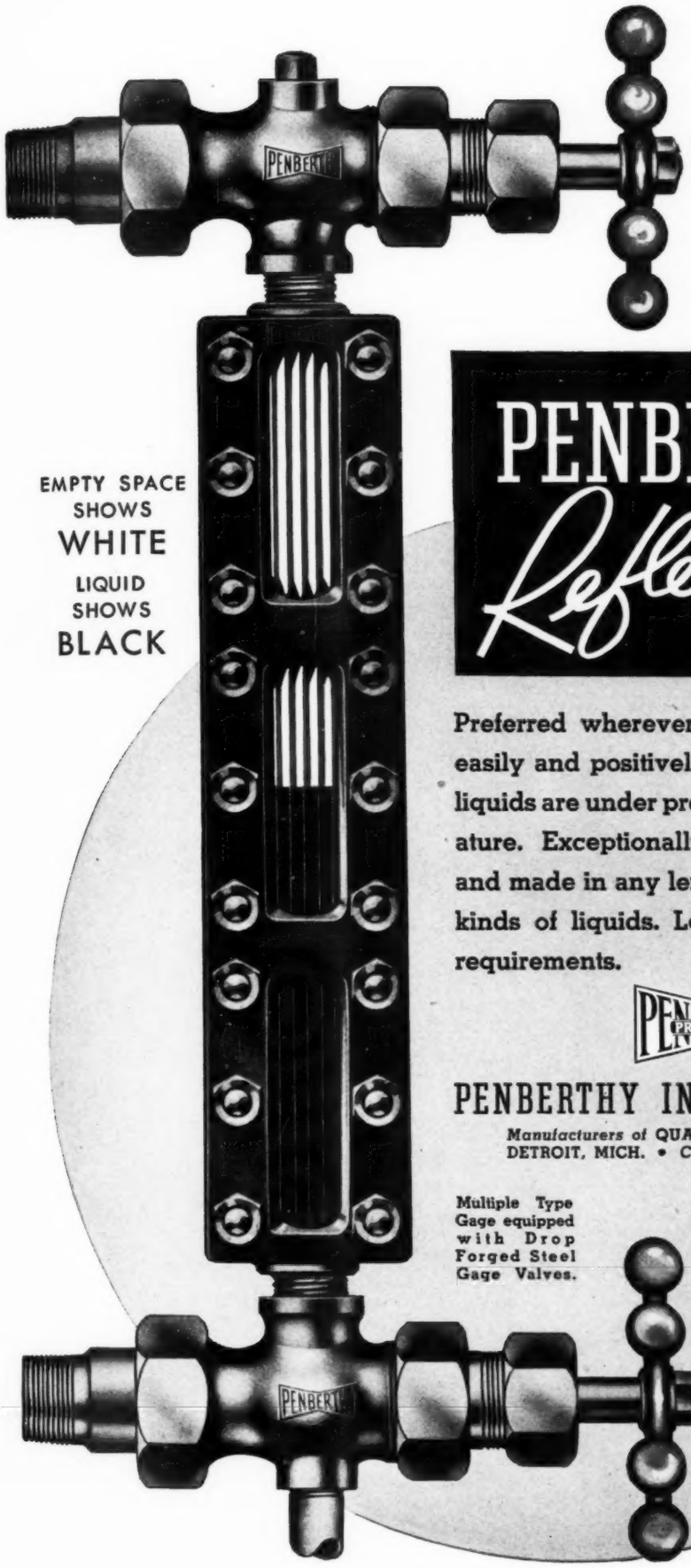
Shell Petroleum Company and Rowan and Nichols, offset owners, attacked the permit for a well on the small tract, Amerada Petroleum Company intervening, upon the grounds that a bona fide dispute existed and also on the contention that it was an inhibited subdivision. The court's opinion, written by Associate Justice M. B. Blair, held that the bare assertion of the claimants to title did not constitute such a bona fide dispute as to deprive the commission of its discretionary power to grant the permit. A previous decision involving Rule 37 had been interpreted as holding that in event of a bona fide title dispute the commission was deprived of its authority to grant an exception permit. The new opinion is considered as clarifying this point.

●

Navy Asks Ownership of Submerged Oil Lands

"Legislation establishing naval ownership of oil in certain submerged lands" is among the eight pieces of legislation Admiral D. Leahy classes as "essential" in the next session of Congress. Admiral Leahy has included this item in a list of legislation that the Navy Department will sponsor. A second item that may affect the oil industry, particularly in California, is the navy's desire for legislation "speeding acquisition of minerals essential to war," also included in Admiral Leahy's list of "essentials."

"Had it not been for emergency action taken by the California Tidelands Association, now the United Landowners Association, last May, in organizing and sending a delegation of representative California citizens and state officials to Washington to take a last minute stand against the measure, the Nye resolution, sponsored by the Navy in the last session of Congress, would have been passed," according to Ralph F. Forch, president of the United Landowners Association. "This resolution directed the U. S. attorney general to take the necessary action to establish Federal ownership over California tideland oil deposits, and was killed in the House Rules Committee only after determined opposition from California."



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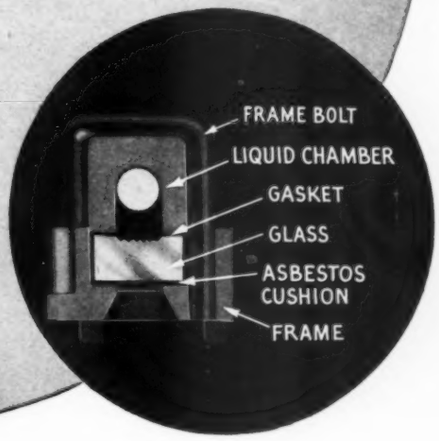

Progress of Major Pipe Line Work

THE Texas Pipe Line Company through its subsidiary, the Central States Pipe Line Company, has awarded to Williams Bros. Company, Tulsa, Oklahoma, a contract for laying a 71-mile pipe line from the Lake Centralia field, Marion County, Illinois, to Lawrenceville in Lawrence County. The Texas Company has a refinery at the latter point. The line also will connect with the South Wayne County field. A total of 38 miles of 8-in. pipe and 33 miles of 10-in. pipe will be laid. One pump station will be constructed, situated in the Lake Centralia field.

The Lake Centralia field was discovered by The Texas Company last summer and has approximately 32 wells producing a total of 10,000 bbl. per day. The new line, however, will have a capacity to transport more than 10,000 bbl., looking to the future when larger runs are expected to be made from the field.

Williams Bros. Company has established an office at Flora, Illinois, in Clay County, and Guy Connors, vice-president, is in charge of the work, which is expected to be completed by November 5th.

•

The Bell Oil and Gas Company, Grandfield, Oklahoma, is constructing a gasoline pipe line from that point to Burkburnett, Texas, where a gasoline terminal will be provided. From this terminal deliveries will be made by truck throughout an area approximately 150 miles square. The Bell Oil and Gas Company has a refinery at Grandfield, but operates mostly on North Texas crudes.

•

To further the development of oil in Alberta, Canada, and as a part of its rearmament plans, Great Britain may construct a pipe line from Alberta fields to Vancouver, Canada, it has been learned. Such a line would be more than 1000 miles in length and would involve an expenditure of about $16,000,000. At present oil production in the Alberta fields is retarded by a lack of markets. Under the new plan gasoline manufactured from the crude would be used for naval purposes. Sir Edward Ellington, British air marshal, visited Canada recently and while there became impressed with the value of West Canadian fields as a source of crude oil in event of war.

The British Government's interest in building such a pipe line followed by about two weeks an offer by a German firm, Tropicorp, Inc., to construct a line from Calgary to Vancouver and to take Canadian oil in payment.

•

The Kansas Pipe Line and Gas Company has made application with the Federal Power Commission for construction of a natural gas line from the Hugoton field, southwestern Kansas, to the northern part of Minnesota. This is the first application made under the provisions of the new federal natural gas act. The total cost of the project will be about $21,500,000. An application has already been made to the Reconstruction Finance Corporation for a loan of $20,000,000. The project would involve the laying of about 1040 miles of trunk line and 1306 miles of lateral lines to various towns along its route, which would be served with natural gas.

The Bituminous Coal Commission supported by coal interests of several states is protesting the proposed line. The Commission has filed a petition with the Reconstruction Finance Corporation, which states in part "displacement of coal from these areas, which would follow expansion of natural gas consumption, would deprive railroads of revenue and divert coal to other markets which are already congested."

•

The Mountain Fuel Supply Company having its headquarters at Rock Spring, Wyoming, has awarded to S. D. Bechtel Company, San Francisco, California, the general contract for laying a 53-mile 18-in. loop from a point near Evanston, Wyoming, to Coalville, Utah. The H. C. Price Company, Bartlesville, Oklahoma, has the contract for electric welding of the line.

•

The proposal to lay an oil pipe line from the K.M.A. field, Texas, to the Gulf Coast is receiving active support from operators in the area and other interested parties. The Hope Engineering Company has offered to construct the line if assured of sufficient crude. The company asked that 300 wells and 10,000 acres be contracted to it within the next five years.

At a recent meeting in Wichita Falls a total of 8,062 acres and 161 wells were pledged, giving rise to the hope that the stipulated volume of production will soon be under contract. The proposed line would have a minimum capacity of 10,000 bbl. and a maximum capacity of 24,000 bbl. a day, it is stated.

•

An 18-in. pipe line bridge over the Salt Fork of Red River about 12 miles north of Hollis, Oklahoma, is being constructed by the Lone Star Gas Company to replace the bridge at that point destroyed by flood waters last Spring. The structure is expected to be completed by December 1st. The bridge will be 28 ft. above the bed of the river and 16 ft. above the high-water mark set by the record-breaking Spring flood. The total length including anchors will be 1034 ft., having a clear span of 600 feet. Two main piers 600 ft. apart will support the structure, each pier being surmounted by two structural steel towers 67 ft. high supporting the main cables from which the pipe cradles are suspended. The main piers will be of reinforced concrete and they will be tied together with a 14-in. web wall and rest on sub-piers consisting of two steel caissons. Wilder Kenan of Mathews and Kenan, San Antonio, Texas, designed the bridge and the contract for construction was let to the Pittsburgh-Des Moines Steel Company.

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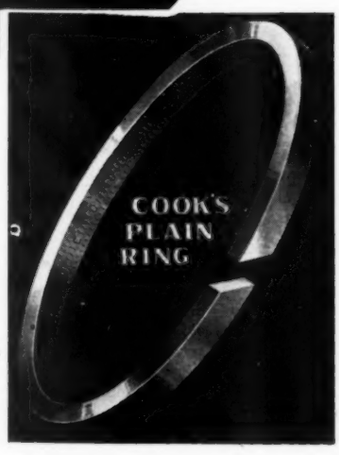

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Latest Activities In The Oil Fields

THE Frannie field, Park County, Wyoming, has been extended a quarter of a mile by Continental Oil Company's No. 1 Northern Pacific. The well swabbed 203 bbl. of oil on the initial test of eight and one-half hours. The 7-in. casing is set at a depth of 3442 feet. Production is from the Embar Tensleep zone, logged from 3464 to 3530 feet.

●

The Champlin Refining Company has completed its No. 1 Herman Boehm, producing 1611 bbl. on an initial 24-hour test, for what may prove to be the discovery well in a new Wilcox sand pool. The well is in northwestern Garfield County, Oklahoma. Initially the water content was reported as varying from 1 to 12 percent.

●

Kerlyn Oil Company's No. 1 Orphanage, a wildcat test north of Oklahoma City, Oklahoma, has been successfully completed, the fourth pool opener for the Britton area. The well was drilled to a depth of 6702 ft. in a break between the first and second Wilcox sands after saturation had been found in the first sand and the dolomite. At that depth a core was taken to a depth of 6707 feet. The 6⅝-in. casing was set at a depth of 6540 feet.

●

A new pool has been opened in Illinois by the Pure Oil Company with its No. 1 Wakefield, northwest of Olney and northeast of the Noble pool in Richland County. The wildcat test was drilled to a depth of 3003 ft., into the McCloskey, but did not produce. It was then plugged-back to a depth of 2583 ft. to test the Cypress sand and swabbed 330 bbl. of oil in 24 hours, no water showing.

●

The limit of the new Shreveport, Louisiana, basal Glenrose lime field has been defined on the southeast edge of the city limits by F. W. Martin's and Superior Oil Corporation's No. 1 Andrew Querbes, in 37-17n-13w. The test either will be abandoned at its present total depth of 6155 ft. or deepened to the lower Marine.

Ralph Pryor, Floyd Lockhart, Gerald Smith, and others apparently have given Cowley County, southern Kansas, a new pool. Their No. 2 Wilson, southeast of Winfield, is flowing oil from Arbuckle dolomite at a total depth of 3517 feet.

●

No. 1 N. S. Hundson of the Austin Corporation and J. W. Heard, a wildcat five and one-half miles from the La Rosa field, Texas, cored a sand body having a good oil showing. The test cored sandy shale having streaks of oil sand at a depth of 4215-31 ft., oil sand from 4231 to 4233 ft., and shale from 4233 to 4235 feet. The operators attempted two drill-stem tests but both failed. At last reports coring was being continued below 4548 feet.

●

A closely watched wildcat test in Kansas is Turner-Saco's No. 1 Umschied in C NE NW of 32-8s-9e, Westmoreland area of Pottawatomie County. A recent report revealed that the test was below 1150 ft. and was said to be running 100 ft. higher than a test in the NW NE of 32-9s-9e, which found the granite at a depth of 1850 ft., after obtaining showings from the Hunton lime at a depth of 1500 ft. and below. The area in which the test is being drilled has been declared by several geologists to be a potentially large field.

●

H. B. Oil Company's No. 1 Rosecrans promises an extension to the Athens-Rosecrans field, California. The O'Dea sand was reported found at a depth of 7300 ft. and again below 7800 feet. Cores taken have oil showings and at last reports the operators were preparing to set 7-in. casing and make a production test.

●

Sid Richardson's No. 2 Sue Alice Slaughter has extended production of the Slaughter pool, Texas, by more than one-half mile. The well was drilled to a total depth of 4989 ft. but was plugged back to 4982 ft. and flowed 816 bbl. of oil on a 24-hour potential test.

AVERAGE CRUDE PRICES

California	
Kettleman Hills	$1.19-1.43
Playa Del Rey	.80-1.16
Coalinga	.70- .90
Signal Hill	.80-1.21
Montana	.90-1.35
Wyoming	.35-1.30
Colorado	.92-1.25
New Mexico	.53- .95
Texas	
North Central	.71-1.13
Panhandle	.67-1.06
West Texas	.53- .95
Gulf Coast	.79-1.28
Darst Creek	.96
East Texas	1.10
Talco	.55
Kansas	.60-1.10
Oklahoma	.60-1.10
Arkansas	.66-1.05
Louisiana	
Rodessa	$ 1.05
Gulf Coast	.74-1.20
North Louisiana	.73-1.05
Illinois	1.05-1.15
Kentucky	1.32-1.40
Indiana	1.05
Ohio	
Lima	.90
Michigan	.74-92.5
Pennsylvania	
Bradford	1.68
Southwest	1.34
Eureka	1.28
Buckeye	1.18
Corning	1.17
Canada	2.10-2.17

DAILY AVERAGE CRUDE OIL PRODUCTION

Data Supplied by A.P.I.

(Figures in Barrels)

	[1]B. of M. Dept. of Int. Calculations (September)	Week Ended Oct. 1, 1938	Week Ended Sept. 3, 1938	Week Ended Oct. 2, 1937
Oklahoma	528,300	454,050	432,400	581,200
Kansas	168,000	159,400	161,200	184,500
Panhandle Texas	.....	68,250	69,000	79,950
North Texas	.....	71,100	70,350	73,750
West Central Texas	.....	28,750	27,950	33,750
West Texas	.....	189,750	220,600	220,850
East Central Texas	.....	89,150	96,950	116,550
East Texas	.....	369,000	441,650	479,200
Southwest Texas	.....	217,700	238,800	272,950
Coastal Texas	.....	202,600	222,000	217,000
TOTAL TEXAS	1,398,600	1,236,300	1,387,300	1,494,000
North Louisiana	.....	73,700	78,350	89,650
Coastal Louisiana	.....	186,900	188,100	174,650
TOTAL LA.	255,300	260,600	266,450	264,300
Arkansas	53,700	57,750	56,900	38,700
Eastern	149,300	181,900	169,300	144,750
Michigan	57,000	50,050	49,700	54,600
Wyoming	65,600	53,500	50,850	57,700
Montana	14,000	13,450	12,650	18,200
Colorado	4,600	3,600	3,600	4,650
New Mexico	111,600	105,800	106,950	114,650
TOTAL EAST OF CALIF.	2,806,000	2,576,400	2,697,300	2,957,250
California	638,300	655,400	651,800	690,200
TOTAL U. S.	3,444,300	3,231,800	3,349,100	3,647,450

[1]These are Bureau of Mines' calculations of the demand for domestic crude oil based upon certain premises outlined in its detailed forecast for the month of September. As demand may be supplied either from stocks, or from new production, contemplated withdrawals from crude oil stocks must be deducted from the Bureau's estimate of demand to determine the amount of new crude oil to be produced.

OUT IN FRONT . . . with Inhibited Acidizing

If ever there existed a vestige of doubt as to the high value of *Inhibited* acid, it should now be utterly dispelled.

Dowell's six-year history, during which time it has treated in excess of 15,000 wells, stands as monumental evidence to the loss-preventing value of an acid that rapidly reduces limestone yet is inactive against tubing, casing and equipment.

Moreover, Dowell maintains accurate control of its acid *strength*. This control begins with the compounding of the acid during manufacture and, as a double safeguard, is constantly checked by study of field samples.

No operator can afford to jeopardize his investment by permitting raw acid of uncontrolled strength to enter his wells.

Dowell is "out in front" today because informed oil men know that Dowell has developed materials and methods of scientific standing. Stay "out in front" with Dowell.

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Dowell's latest achievement—a new principle of acid action. Dowell "XR" Acid is kept active till it travels far into the pay zone. Get the facts on Dowell "XR" from any Dowell office. There is no price premium for this new acid. It is offered where applicable at the same price as the famous Dowell "X".

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Subsidiary of THE DOW CHEMICAL COMPANY
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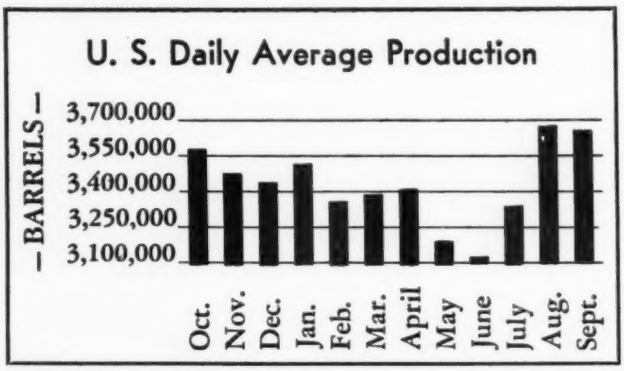
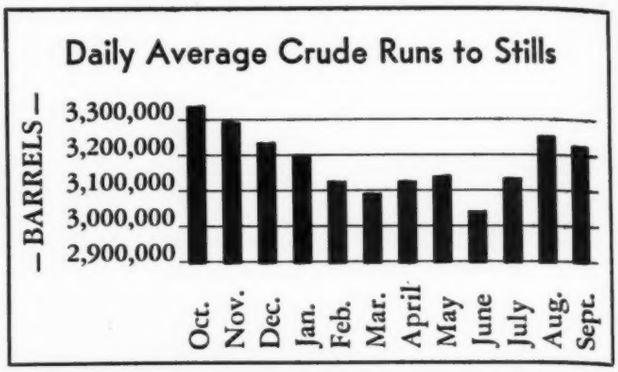
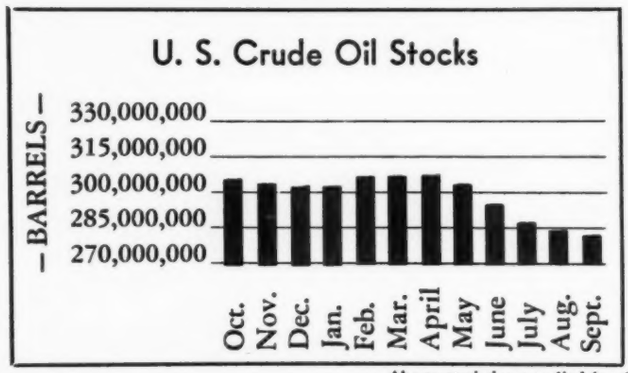
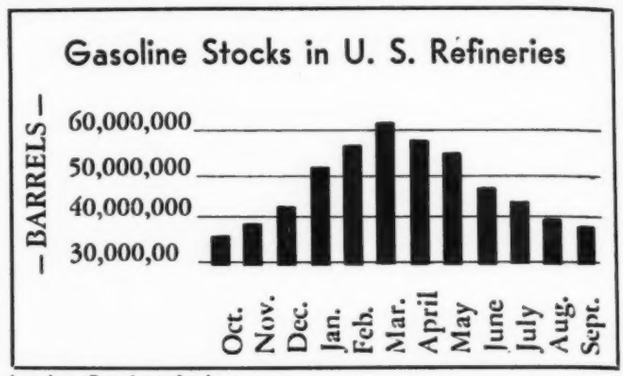
OIL AND GAS WELL CHEMICAL SERVICE

Summary of Petroleum Statistics and Field Activities









Above statistics supplied by the American Petroleum Institute.

Summarized Operations in Active Fields for September, 1938

Fields	Completions	Producers	Rigs	Drilling Wells	Depth of Production	No. Casing Strings	Gravity of Oil	Type of Tool Used
Texas								
East Texas	117	116	20	37	3500-3700	2	40	Rotary
Duval County	60	47	6	18	1554-2900	2	22	Rotary
Ector County	57	56	6	69	3675-4377	2 and 3	32-36	Rot.-Cab.
Panhandle	52	50	37	132	1700-3900	2	40	Rotary
Refugio County	21	21	3	14	4900-5900	2	38	Rotary
Nueces County	23	20	7	20	3922-5878	2 or 3	21-54	Rotary
Winkler County	18	18	8	17	2850-3450	2 and 3	30-38	Rot.-Cab.
K. M. A. Field	74	69	35	58	3730-3935	2	42-43	Rot.-Cab.
Oklahoma								
Oklahoma City	3	2	4	9	6450-6682	3	39	Rotary
Fitts Pool	22	15	2	6	1800-4488	2 or 3	38	Rotary
Kansas								
Russell County	16	11	4	31	2926-3435	2 and 5	32-37	Rot.-Cab.
Rice County	21	16	2	18	3222-4085	2 and 5	42-48	Rot.-Cab.
Barton County	24	17	3	17	3290-3518	2	39-42	Rot.-Cab.
Louisiana-Texas-Arkansas								
Rodessa	11	11	6	11	5950-6450	3	39	Rotary
Illinois								
Central Illinois	178	122	16	311	2950-4100	2	36-38	Rot.-Cab.
New Mexico								
Lea County	32	31	13	83	3150-4030	3	30-34	Rot.-Cab.
California								
Kettleman Hills	1	1	2	11	8900-8730	3 or 4	40	Rotary
Wilmington	21	21	9	19	3500-4000	2 and 3	18-20	Rotary

Field Activities by States for September, 1938

State	Completions		Producers		Locations		Rigs		Drilling Wells		Production, 1937 (In Barrels)
	September	August	September	August	September	August	September	August	September	August	
Arkansas	16	18	13	14	19	19	15	16	36	35	12,088,341
California	124	121	107	99	112	74	96	107	209	230	238,587,663
Colorado	1	....	0	....	....	....	2	2	25	24	1,532,893
Illinois	173	207	120	150	....	....	170	173**	101	102	7,376,022
Indiana	17	9	13	2	....	....	5	4	45	35	820,000
Kansas	154	135	119	98	162	145	34	36	202	200	70,542,000
Kentucky	106	78	66	62	....	....	10	9	106	102	5,500,000
Louisiana	102	100	63	66	81	110	40	47	191	203	90,501,068
Michigan	115	95	66	46	141	92	25	24	130	129	16,254,181
Mississippi	....	....	....	....	....	....	6	4	3	5	Gas Prod.
Montana	6	11	6	11	....	....	4	4	56	59	5,775,000
New Mexico	42	56	37	49	....	....	15	15	131	136	38,642,184
New York	42*	43*	37	41	....	....	....	....	....	....	5,466,200
Ohio	102	85	75	56	....	....	46	45	120	148	3,547,600
Oklahoma	186	162	123	108	215	162	50	59	222	290	225,402,731
Pennsylvania	163*	165*	151	157	....	....	....	....	....	....	19,154,400
Texas	1012	1040	780	803	1094	1037	311	357	1154	1207	506,891,233
West Virginia	64	56	52	46	....	....	27	24	126	119	3,833,000
Wyoming	6	9	5	6	....	....	5	6	59	56	19,402,121
Total	2431	2390	1833	1814	1824	1639	861	932	2916	3080	1,271,316,637

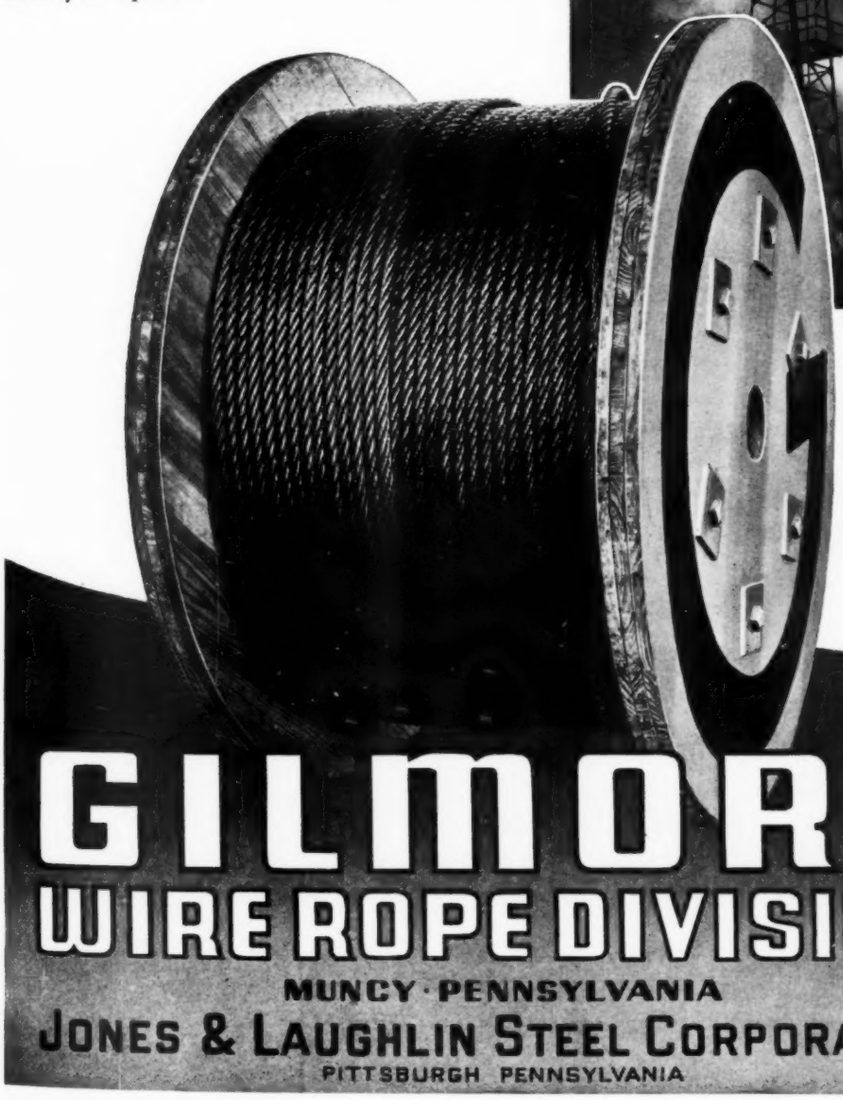
*Includes water-intake and pressure wells.
**Includes 44 rigging up and 129 rigs standing.

EVERY operator in the Oil Field likes a line that performs perfectly and keeps on performing for a longer period.

The new Gilmore Plant was equipped with one particular thing in mind — that of making a non-rotating line that will give perfect and lasting performance . . . so we want you users of this type of line to give us a chance to put a happy smile upon your face with a Gilmore non-rotating line for your rotary rig.

Now occasionally you run into Salt Water and bad going. That's when you need Gilmore precision lines. They have no interstices . . . all strands are closed perfectly and with utmost precision.

Nearly all other manufacturers paint one of the strands of their Wire Lines of highest Tensile Strength. We don't . . . because we cannot lubricate a strand and paint it. Neither can anyone else. We think you would prefer lubrication instead of paint . . . so do we. There are many other reasons worth investigating . . . won't you let us replace your line with a Gilmore Line the next time? We invite your opinion.



Other J & L Steel Products:
J & L A.P.I. Casing, Tubing, Drive Pipe and Line Pipe in seamless and welded; J & L A.P.I. Seamless Drill Pipe; J&L Integral-Joint Drill Pipe; J & L Bell and Spigot Casing; J & L Seamless Boiler Tubes; J & L Standard Pipe in seamless and welded; steel products for construction and maintenance.

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The Month's Activities in Refining

Percent Refining Capacity Operated

Western Division, 73.1 Percent **Central Division, 73.9 Percent** **Eastern Division, 86.1 Percent**

THE Ben Franklin Refining Company, Ardmore, Oklahoma, completed remodeling and on October 2nd placed in operation the refinery recently acquired from the Wirt-Franklin Petroleum Corporation. Initially the plant is processing 5000 bbl. of oil per day.

●

Officials of the Gulf Oil Corporation announce an acid-treating unit having 8250-bbl. capacity is to be installed at its Girard Point Philadelphia refinery. The same company recently placed in operation an acid-treating unit of 12,000 bbl. capacity at its Port Arthur, Texas, plant.

●

Contracts for two Koppers phenolate plants for the purification of refinery still gas have been awarded by the Sun Oil Company to Koppers Company's Engineering and Construction Division.

A plant employing a two-stage system and having a capacity of 10,000,000 cu. ft. of gas per day is to be erected at the oil company's Toledo, Ohio, refinery. A single-stage plant for the Marcus Hook, Pennsylvania, refinery will have a daily capacity of 12,000,000 cu. ft. of gas.

This process, developed by Koppers Company, uses a sodium phenolate solution for low cost removal of hydrogen sulphide from refinery still gas. This may be converted into sulphuric acid for plant use or for the market.

●

The natural gasoline plant constructed jointly by the Union Oil Company and the Superior Oil Company in the Rio Bravo field, Kern County California, is now in operation, processing approximately 5,000,000 cu. ft. of gas per day and manufacturing 3000 gal. of natural gasoline. The rated capacity of the plant is 20,000,000 cu. ft. per day and provision has been made so that equipment can be added to increase this capacity.

●

The British-American Oil Company's new refinery in East Calgary, Alberta, Canada, is now under construction. The plant will be completed and placed in operation by May 1st, it is anticipated. L. E. Wooley is manager of refineries for the company and M. S. Berlinger is construction superintendent.

The Barnsdall Refining Corporation on October 15 closed its refinery at Barnsdall, Oklahoma. The plant has been processing about 4000 bbl. of crude oil per day. Low prices for manufactured products is said to be reason for discontinuing operations at the Oklahoma plant. The company will continue to operate its plants at Wichita, Kansas, and Corpus Christi, Texas, each of which has a daily capacity of 5000 barrels.

●

Erection of a 3000-bbl. refinery in Western Kansas is being considered by the Consumers Coöperative Association, it is announced. Plans call for construction work to begin late in the fall and the plant will be placed on stream in the spring. The refinery will be incorporated under the laws of Kansas and will distribute its manufactured products throughout western Kansas, eastern Colorado, and western Nebraska, if present plans are consummated.

●

The benzol-ketone solvent dewaxing plant being erected by the Sinclair Refining Company at Wellsville, New York, to replace the plant recently destroyed by fire is expected to be completed some time in January. The capacity of the unit, which is being constructed by the Lummus Company, will be 3000 bbl. per day.

●

The Eason Oil Company has discontinued temporarily the operation of its refinery at Enid, Oklahoma. Inability to purchase the required amount of crude oil necessary for the operation of the skimming plant is the cause of the shutdown, according to T. T. Eason, president of the company. The cracking plant already was shutdown as a result of a recent fire. It is being rebuilt at the present time.

●

The Danube Oil Corporation has begun construction of a vapor-recovery unit at its 400-bbl. skimming plant near Borger, Texas. The new unit, which will operate on refinery vapors, is expected to be completed by November 1st. The natural gasoline thus manufactured will be used to blend with straight-run gasoline.

Crude Runs to Stills, Gasoline and Gas and Fuel Oil Stocks
Week Ending October 1, 1938

A.P.I. Figures

(Figures in Barrels of 42 Gal. Each)

DISTRICT	Percent Potential Capacity Reporting	Daily Avg. Crude Runs to Stills	Percent Operated of Total Capacity Reporting	Total Motor Fuel Stocks Thousands of Bbl.	Gas and Fuel Oil Stocks Thousands of Bbl.
East Coast	100.0	515,000	83.7	18,328	15,988
Appalachian	85.9	102,000	79.7	2,920	914
Ind., Ill., Ky.	89.0	461,000	94.9	10,551	9,378
Okla., Kans., Mo.	81.6	256,000	74.9	5,909	4,587
Inland Texas	50.3	104,000	65.4	1,606	2,005
Texas Gulf	88.9	758,000	90.5	9,812	14,251
La. Gulf	97.3	109,000	75.2	2,240	3,224
No. La. & Ark.	55.0	35,000	63.6	499	812
Rocky Mt.	54.2	50,000	78.1	1,111	835
California	90.0	508,000	68.2	12,086	96,475
Reported	85.5	2,898,000	81.0	65,062	148,469
Estimated Unreported		337,000		3,540	3,290
*EST'D TOTAL U. S. OCT. 1, '38		3,235,000		68,602	151,759
*EST'D TOTAL U. S. SEPT. 24, '38		3,220,000		68,605	150,468
U. S. B. of M. *OCT. 1, '37		**3,450,000		65,466	116,164

*Estimated Bureau of Mines' basis.
**September, 1937, daily average.

THE Petroleum Engineer

OCTOBER, 1938

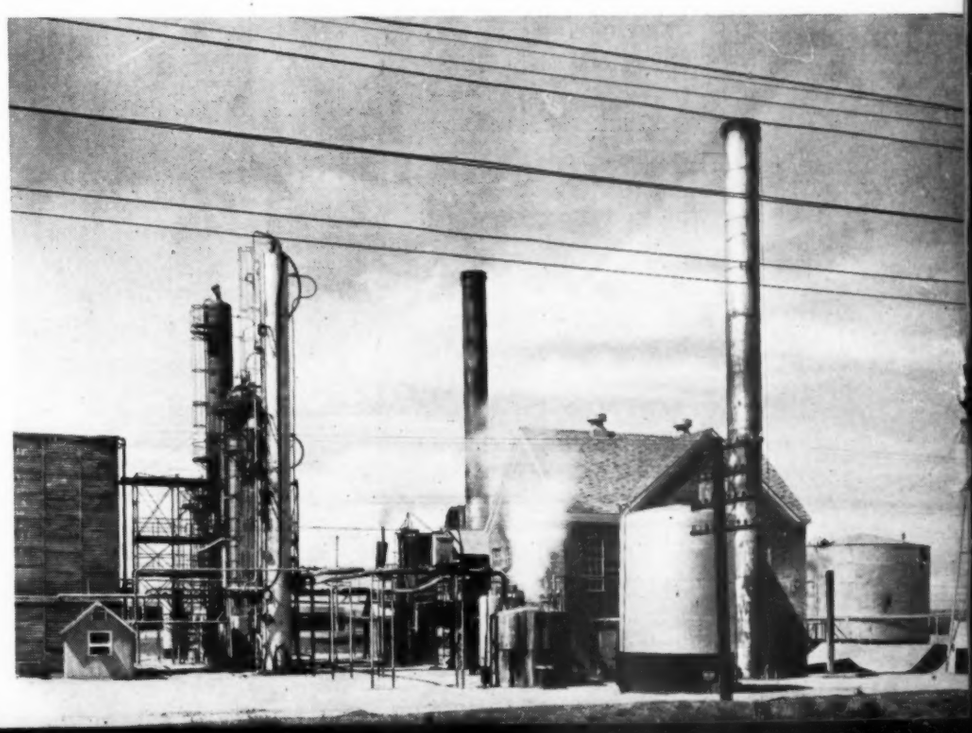
Combination Topping and Cracking Plant Produces Large Yield of Gasoline

Approximately 63 percent of the high-gravity paraffin-base crude charge becomes finished gasoline

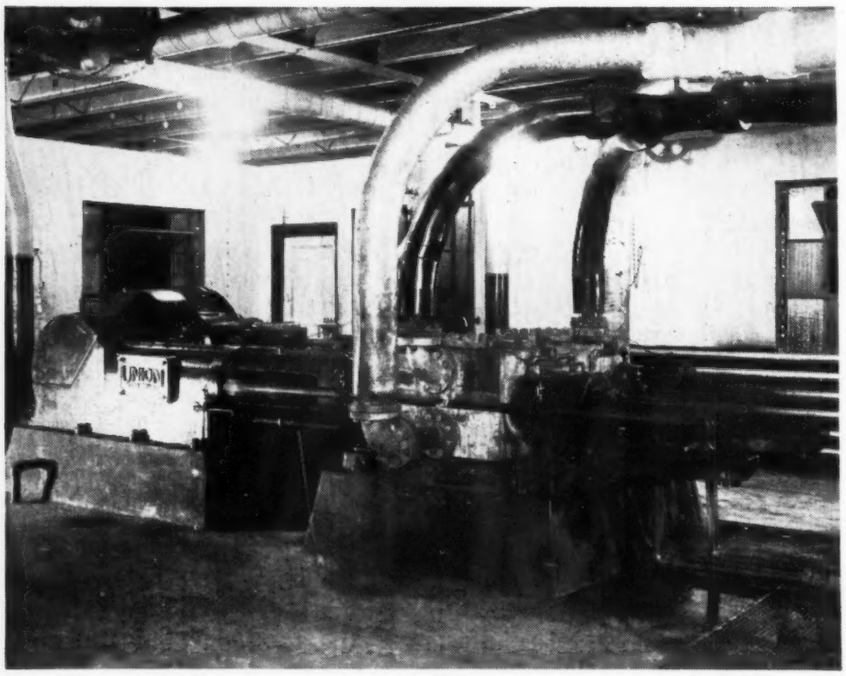
By J. C. ALBRIGHT

BAY Petroleum Corporation's refinery at Denver, Colorado, was designed by Ampco Engineering Company, Dallas, Texas, and construction was supervised by engineers of Universal Oil Products Company, Chicago, Illinois. The company is licensed to use the Dubbs cracking process. One part of the plant is an independent topping unit and the other a topped crude cracking plant. Either may be operated separately, or they may be so synchronized that residuum or topped crude from the skimming plant can be charged directly to the cracking plant while hot.

A high-gravity paraffin-base crude containing a large percentage of gasoline is shipped to the plant by tank car from Lance Creek, Wyoming, but arrangements are now being completed to obtain crude transported from the northern fields by pipe line, thus avoid-



Bay Petroleum Company's Denver, Colorado, refinery



Steam pump

ing the long haul by tank car from eastern Wyoming to Denver. The bottoms are suitable for reduction to high-octane gasoline and industrial fuel oil. Processing this type crude in the synchronized units, Bay Petroleum Corporation is realizing an overall yield of 63.53 percent endpoint gasoline, the total loss, including the uncondensible gases, being only 4.88 percent of the fresh crude charge.

About 2750 bbl. of crude per day is delivered from the storage tanks by a 10-in. by 6-in. by 10-in. duplex steam-driven reciprocating pump, operating at about 200-lb. pressure. The charge passes through a heat exchanger in which it receives heat from the cracking-plant pressure distillate. This is a shell-and-tube unit having 2324 sq. ft. of heating surface. The crude passes through the tubes and distillate through the shell. The crude then passes through a second shell-and- tube heat exchanger, installed in the vapor line from the cracking-plant flash chamber. This exchanger contains 220 sq. ft. of heating surface. A 3-in. line carries the crude thence to the topping furnace. This furnace contains four sets of 3½-in. O.D. tubes 24 ft. in length, arranged in a convection bank of 40 tubes, a set of 16 floor tubes, 10 radiant tubes, and 48 tubes in the roof. All tubes have 6-gauge walls. The crude passes through the tubes in the order given. The heated crude leaves the furnace through a 3-in. line to the atmospheric topping tower.

This column is 4 ft. 6 in. in diameter and 65 ft. 6 in. high. It contains three stripper sections in which various products are manufactured to specification and withdrawn from the column without the necessity of outside "bootlegs" or auxiliary towers. Counting from the top, the first of the three draw-off sections, or strippers, is set between the 5th and 6th steel bubble trays; the second between the 10th and 11th, and the third between the 14th and 15th. The condensate from each stripping section passes through an outside pipe to return through the downcomer of the plate immediately above, entering a pan in the stripper, under which is a steam spider that fractionates the cut to specification. The product spills downward to the collector and out the withdrawal line to coolers and accumulator drums or run-down tanks. Ordinarily 62.3-deg. gravity gasoline is withdrawn from the top of the atmospheric column, 44.5-deg. gravity distillate from the first stripper section, 41.5-deg. gravity domestic burner fuel from the second section, and, if required, a gas oil from the last section. Topped crude, or raw oil for cracking plant charge as it is termed in the Denver plant, is taken from the base of the column in the usual manner.

The crude leaves the topping furnace at a transfer temperature of about 610 deg. fahr., and enters the column through a 3-in. nozzle placed between the 19th and 20th trays. Process steam enters at the base to assist in fractionating the charge. A liquid-level controller regulates the height of topped crude in the vessel and controls the speed of the raw oil pump, which delivers the topped crude directly to the cracking-plant fractionating column, or through the topped-crude pipe coolers to storage.

The gasoline vapors pass through a 6-in. vapor line to the main condenser, which contains 2324 sq. ft. of surface and which cools the product to a temperature of about 80 deg. fahr., depending upon atmospheric conditions. This gasoline is accumulated in the atmospheric-tower reflux receiver, a vessel 3 ft. by 4 ft. 6 in. in size, through which passes all the straight-run gasoline from the main condenser, and from which is drawn the reflux necessary for column control. The gasoline enters the side of the reflux condenser through a 4-in. nozzle and strikes a splash plate, placed four in. from the nozzle to prevent excessive agitation of the liquid in the vessel and to allow moisture condensed with the gasoline to settle so that it will not be recirculated by the reflux pump. The duplex, steam-driven 7½-in. by 4½-in. by 10-in. reciprocating pump circulates sufficient liquid to maintain the temperature at the top of the atmospheric tower at about 330 deg. fahr. to control the endpoint of the product. The reflux enters the column above the top bubble tray opposite a 16-in. manhole placed in the column to facilitate inspection.

The average temperature of the topped crude in the base of the atmospheric column is about 570 deg. fahrenheit. The 10-in. by 7-in. by 10-in., duplex, steam-driven, reciprocating raw-oil pump, running at about 1110 strokes per hour, delivers the hot bottoms to the cracking-plant main fractionating column. The charge enters

this vessel above the 18th tray, which is one of the side-to-side pans. The column contains 16 cast-iron bubble decks and ten cast-iron side-to-side pans. It is 5 ft. in diameter and 61 ft. 6 in. high, and is provided with one 24-in., eight 16-in., and ten 8-in. manholes. One drawoff section is provided, installed between the 11th and 12th bubble pans, where the light oil is received and from which absorption oil and low-pressure cooling oil are withdrawn.

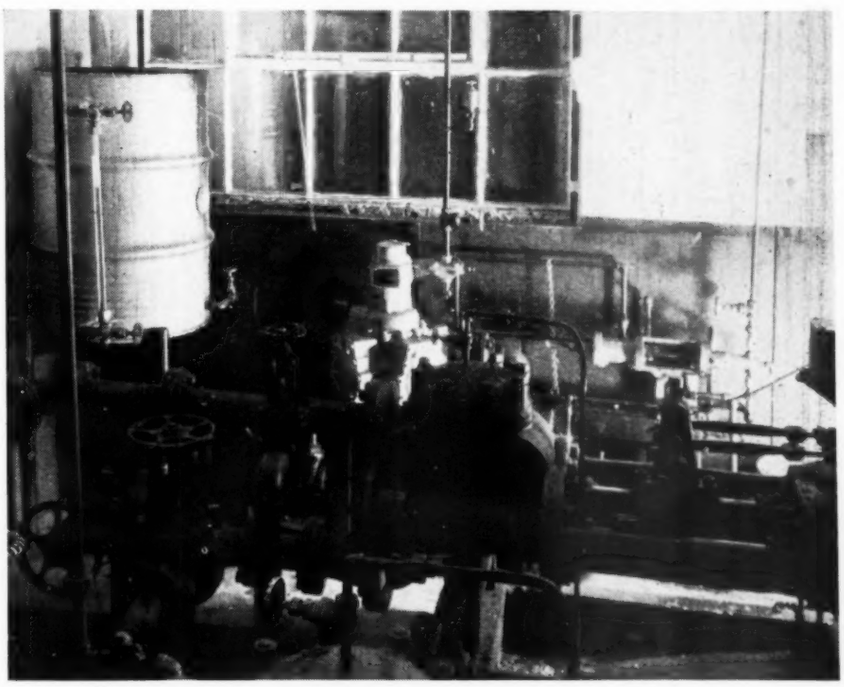
Material from the base of the main fractionating column has a gravity of about 20.8 deg. A.P.I. and a temperature of about 725 deg. fahrenheit. A 4-in. by 16-in. steam-engine-driven, outside-plunger-packed, hot-oil pump, running at about 1920 strokes per minute and at a pressure of about 500 lb. gauge, pumps the material through a 3-in. charge line directly to the cracking plant heater. This furnace is an upshot unit containing 160 alloy tubes 2½-in. O.D., 2-in. I.D., 24 ft. in length, arranged in two sets; the first set, of 74 tubes, processes heavy oil and the second, containing 86 tubes, processes light oil from the main fractionating column. The furnace has two sets of burners, 12 on each side, six for gas and six for industrial fuel oil for warming-up and coming on-stream. The furnace is equipped with a center bridgewall, against which the flames impinge. The tubes are supported on the outer walls and in the top of the heater.

The heavy oil enters the cracking furnace at the top through a 3-in. charging line, which is connected to the first row of convection tubes. The oil flows downward through 32 of these tubes, enters six shock tubes, and discharges to the tubes in the sloping roof and to the tubes supported on the side-wall. The furnace temperature in the heavy oil process side is about 1225 deg. fahr., and the temperature of the stack gases averages about 900 deg. fahr. at the top section of convection tubes. Stocks from cracking tubes pass from the furnace through a 2½-in. transfer line at a temperature of 930 deg. fahr. to the reaction chamber and enter it through an up-turned wall-washing connection near the top manhole.

Light oil, of about 26.5-deg. gravity, is withdrawn from the main fractionating column of the cracking plant at the accumulator section between the 11th and 12th bubble decks. A 3½-in. by 12-in. outside-plunger-packed, steam-driven hot-oil pump, operating at a speed of about 2210 strokes per hour against a back-pressure of about 470 lb. gauge, pumps this material through a 2-in. charge line to the tubes in the light oil cracking bank of the cracking plant heater. The charge flows downward from the convection section through shock tubes and a double row of side-wall tubes, and leaves the furnace heating section at a temperature of about 975 deg. fahr., but the transfer temperature is about 1010 deg. fahrenheit. Furnace temperature on the light oil cracking side is about 1310 deg. fahr. and the temperature of the stack gases is the same as that of the stack gases on the heavy-oil side. The charge enters the reaction chamber through a down-turned 2½-in. nozzle inserted in the chamber at a point opposite the heavy oil nozzle.

The reaction chamber is 3 ft. 10 in. in diameter and 33 ft. 6 in. high. The walls are 2⅛ in. thick and are insulated by a 5-in. blanket. Outlet pressure is controlled by an automatic pressure- and flow-controller, instead of the usual manually operated valve. This controller is fitted with alloy valve seat and stem, which withstand corrosion, erosion, and carbon deposits satisfactorily. The pressure maintained on the reaction chamber is about 275 lb. gauge, and the outlet temperature is about 870 deg. fahr. at the point of introduction of the low-pressure cooling-oil nozzle. Material flows through a 3-in. line to the flash chamber, entering through the side to be distributed by a section split from a piece of 8-in. pipe, set horizontally and provided with a wear plate at the opposite end to protect the walls of the flash chamber. This chamber is 5 ft. 6 in. in internal diameter and 40 ft. in height. The walls are 11/16 in. thick and are insulated with 3-in. cover. Inlet temperature of the flash chamber is about 865 deg. fahr., the top temperature is about 785 deg. fahr., and the draw-off temperature is about 830 deg. fahrenheit. Low pressure cooling oil in quantities sufficient to control the quality of vapors released from the flash chamber to the fractionator is pumped through a 1½-in. weighted spray placed near the vapor outlet.

A 6-in. line leads from the top outlet of the flash chamber to the crude



Unit for handling chemicals

heat exchanger, thence to the inlet nozzle of the fractionator, installed beneath the bottom side-to-side pan. Fuel oil, of about 7.6-deg. gravity, is released through a liquid-level controller to flow through coolers to storage for shipment as fuel oil, or is blended for other purposes. The temperature at the top of the fractionator is maintained at about 375 deg. fahr. and the inlet temperature is about 770 deg. fahrenheit. Overhead vapors pass through a 6-in. vapor line to the crude heat exchanger, thence to the main condenser, and to the pressure distillate receiver. This vessel is 4 ft. by 10 ft. in size, and is equipped with a liquid-level controller and baffles for controlling splash of pressure distillate. The walls are 5/16 in. thick. A 10-in. by 7-in. by 10-in. pump refluxes part of this material to control overhead temperature and quality of product. Reflux enters the fractionating column through a 2½-in. line above the top bubble tray and opposite the 24-in. manhole.

A 7½-in by 4½-in. by 10-in. duplex steam pump delivers the pressure distillate to the stabilizer heat exchanger at a temperature of about 100 deg. fahrenheit. The heat exchanger contains 225 sq. ft. of surface and is covered with 2-in. insulation. The pressure distillate passes through a 1½-in line to the fractionator or stabilizer, which it enters at a point between the 14th and 15th bubble decks. The stabilizer is 3 ft. in diameter and 36 ft. high, and contains 26 cast-iron bubble decks. Its walls are ½ in. thick, and are covered with 2-in. insulation. The reflux condenser consists of 252 sq. ft. of cooling surface. Water enters at a temperature of about 80 deg. fahr. in sufficient quantity to produce a top temperature of about 145 deg. fahrenheit. Vapors leave the fractionator below a blind trap in the top of the column, flow through the overhead reflux condenser, and return through a 6-in. connection to the top of the column; uncondensed gases pass through a 1½-in. line to the plant fuel lines or the absorber.

Stabilized pressure distillate passes through 5-in. piping to the column reboiler, which contains 188 sq. ft. of tube surface within the shell and is heated by part of the light oil charge. A 7½-in. by 4½-in. by 10-in. duplex steam pump draws the light oil through a 3-in. line and discharges it through a 2-in. line to the reboiler tubes in sufficient quantity to maintain a reboiler temperature of 335 deg. fahrenheit. Stabilized pressure distillate of the required vapor pressure returns through a 1½-in. line to the stabilizer heat exchanger, then passes through a second unit, having 225 sq. ft. of tube surface, in which water is used to cool the distillate to a temperature of about 85 deg. fahr., and then flows through a 1½-in. pipe to storage.

Uncondensed vapors from the pressure-distillate receiver drum enter the absorber at the top of the lower third through a 3-in. nozzle at a pressure of about 50 pounds. The absorber is 3 ft. in diameter and 19 ft. in height, and contains 12 cast-iron bubble decks. Residue gas leaves through a 2½-in. line to the fuel system. Absorption oil is drawn from the suction piping of the light oil charge pump by a 6-in. by 3½-in. by 6-in. duplex steam pump, is pumped through a set of shell-and-tube coolers containing 870 sq. ft. of surface, which reduces the temperature to about 85 deg. fahr., and is then pumped through a 1½-in. line to the second bubble deck of the absorber. From the absorber the rich oil is pumped by a 6-in. by 3½-in. by 6-in. duplex steam pump to the low-pressure cooling system for reprocessing to recover the absorbed gases.

Results of the operation of this plant, when charging 42.5-deg. A.P.I. Lance Creek, Wyoming, crude are as follows:

CHARACTERISTICS OF PRODUCTS

Distillation	*Crude*	*Topped Crude*	*Light Oil*	*Cracked Gasoline*	*S. R. Gasoline*	*Kerosene Distillate*	*Burner Fuel*	*Fuel Oil*
Gravity, deg. A.P.I.	42.4	29.1	26.6	59.3	62.6	44.6	40.7	7.9
Color				Green	30	30	18	
Doctor				Sour	Sweet	Sweet	Sweet	
Corrosion				Positive	Negative	Negative	Negative	
Octane				66.8	46.2			
R.V.P.				8.0	6.9			
Flash						150° F.	182° F.	160° F.
Vis. at 122 deg. fahr.								216 sec.
I.B.P.		416° F.	250° F.	96° F.	102° F.	390° F.	428° F.	.3% B.S.
10%			448	138	156	411	465	
20%			464	157	185	417	478	
30%			485	186	206	422	489	
40%			493	225	230	427	498	
50%			506	246	251	434	508	
60%			519	276	277	439	519	
70%			537	298	297	446	526	
80%			562	327	326	455	547	
90%			597	354	356	470	564	
95%			618	374	380	486	578	
Dry			640	388	386	518	604	
Recovery			99%	97%	98%	99%	99%	

SKIMMING PLANT

Commodity	*Deg. A.P.I. Gravity*	*Volume, bbl.*	*Percent*
Crude charge	42.5	2719.17	100.00
S.R. gasoline	62.3	1015.98	37.36
Distillate	44.5	165.54	6.09
Burner fuel	41.5	344.54	12.65
Cracking stock	29.4	1065.92	42.88
Loss		27.19	1.00
Total		2719.17	100.00

CRACKING PLANT

Commodity	*Deg. A.P.I. Gravity*	*Volume, bbl.*	*Percent*
Charging stock	29.4	1165.92	100.00
Gasoline, P. D.	59.4	711.77	61.03
Residuum	7.6	348.77	29.91
Gas and loss		105.38	9.06
Total		1165.92	100.00

COMBINED OUTPUT COMPUTED AGAINST CRUDE CHARGE

Commodity	*Percent Yield*
Gasoline	63.53
Distillate	6.09
Burner fuel	12.67
Residuum	12.83
Loss	4.88
Total	100.00

Responsibilities of Engineers in Making Appraisal Reports

By ALEXANDER B. MORRIS
Petroleum Engineer, Tulsa, Oklahoma

"It is conceded by Counsel for the (Securities and Exchange) Commission that the . . . lease is a good lease, and Counsel attacks the engineer's estimate *only* upon three grounds (a) as containing arithmetical mistakes, (b) as not being made in accordance with accepted engineering practice and (c) as giving a result out of line with practical experience in the Oklahoma City field." (Italics supplied.)

OTHERWISE it was a good appraisal. The worst feature is that, in the brief in support of a motion to issue stop order in a registration case before the Securities and Exchange Commission, from which the above quotation is taken, the engineer who made this excellent report was mentioned by name. It may be imagined that his face was red when this modest statement of his efforts was made public.

The releases of the Securities and Exchange Commission and the cases reported in the S. E. C. Reporter series form a body of literature that every engineer engaged in appraisal of industrial or natural resources would do well to consult carefully and frequently. In those publications and in the various proceedings before the Commission law is being made in respect to the duties of experts who offer appraisals of properties that are intended to support new issues of "securities." In the case quoted it would appear that gross negligence or gross incompetence had been shown. It is worthwhile to review the points in which the counsel for the Commission found this report defective, as some of the argument has new and interesting implications.

The fault mentioned in the first objection recited cannot be defended on any grounds. There is no excuse for arithmetical errors in a completed report, especially if all the mistakes are in the same direction, all tending to establish a higher value. Even though the magnitude of the errors is not great, as appears to have been true in this case, their mere presence indicates a carelessness in preparation that casts a shadow upon the validity of the entire work and upon the ability of the person submitting the report. Careful checking, a troublesome nuisance to be sure, will guarantee freedom from criticism on this score, and every engineer owes it to himself no less than to his client to ascertain that his reports are as free from such mistakes as is humanly possible.

The second objection is somewhat more controversial. It was based upon several grounds, but chiefly on these two: (1) failure to apply a factor for shrinkage between original situs and the run tank, and (2) failure to allow for a known gas-cap in estimating ultimate recovery. The first lapse was in respect to a property in the Oklahoma City field. There is some room for argument on whether the shrinkage factor of 30 percent, determined as appropriate to correct for shrinkage at original reservoir pressures, was still appropriate for a valuation as of December, 1935, but without doubt some factor should have been applied to reflect this shrinkage. Similarly, if the volumetric method is adopted and a gas cap is known to exist the estimated volume of this gas cap must be deducted from the total pore space. This omission, coupled with the fact that the wells on the lease were unable to make their allowable production, resulted in an estimate of future recoverable oil 15 times as great as the estimate made by the Commission's engineer, a very able and careful engineer of the highest integrity.

The third point of weakness mentioned, that the results were not in line with practical experience in the field, merely calls attention to the tendency of all professional groups, engineers, lawyers, and doctors alike, to regard themselves as a sort of priesthood, and their dicta, however obviously absurd, as having some sort of inherent cabalistic or magic quality that will compel belief merely by the fact of utterance. As a matter of fact, no one is compelled to believe anything merely because it contains some conventional formula or a lot of Latin phrases, or consists of an illegible scrawl preceded by an ℞. Furthermore, it is wholesome for the work of engineers to be sumitted to competent critical examination by someone who will not swallow specious arguments whole. The work of lawyers is examined by the courts, nothwithstanding that nearly all judges are lawyers too, and the doctors have the undertakers to dispose of their errors. Now the engineers and accountants have the S.E.C. to reckon with in developing the imaginative side of their natures.

In discussing the report of another engineer on some East Texas properties in connection with the same registration, the brief stated:

> "The engineer's estimate of oil which would be recovered from the Registrant's property in the East Texas field was fatally defective in that it was based on the assumption that the major part of the oil to be recovered would be drained from under leases adjoining Registrant's properties, whereas such drainage is forbidden by the applicable law of Texas."

Just how far an engineering report on values should go in considering quasi-legal aspects of value it is difficult to say, as heretofore it has not received much attention. Most engineers in the field would say, off hand, that the above statement was nonsense. A little thought on the subject will reveal that this is not true, and that many such factors are habitually considered as a matter of course. Proration restrictions would come under the head of quasi-legal aspects of value, as would well-spacing agreements, whether wholly voluntary or made at commission order. Certainly no honest engineer would fail to give weight to past, present, or probable future proration measures in evaluating a property. No one would fail to give weight to drilling density; however, it is not ordinarily considered to be incumbent upon an engineer to pass upon the validity of titles. This is a subject upon which few engineers are competent to pass an opinion. Certainly the extent of the interest covered by the report should be accurately indicated. This was one of the arithmetical mistakes already mentioned. In nearly every property this can be definitely determined by a cursory examination of the client's title file, and checked against the actual percentage being paid by the pipe line, if the property is productive. If some doubt still exists

as to the extent of the interest owned, mention should be made of this fact, or a general denial of liability for the accuracy of title information should be made in the preamble to the report. These are matters about which there can be no serious question.

The brief that we have been discussing, however, seeks to place upon engineers the further duty of determining the legality of the issuance of the permits under which the present producing wells were drilled. In accordance with the Texas Supreme Court decision in Brown v. Humble Oil and Refining Company (83 S. W. 2d. 935) if the permits have been illegally issued, production from the wells can be enjoined at the suit of any adjacent owner. The engineer's estimate based on physical considerations may therefore, as a result of legal process, never be realized. This is a new aspect of valuation work, and one that engineers should resist having dumped into their laps. It entails not only investigation of the circumstances of issuance of all permits, but also a practical title history of the tract itself. The client looks to his lawyer for information about any litigation affecting his properties. If not only litigation that has been started is to be considered as affecting value, but also any that may later be instituted by someone who has unearthed some possibly valid grounds, then it is certainly the lawyers and not the engineers who should be expected to make appropriate comment. The engineers, however, should protect themselves by blanket statements to the effect that their values apply to properties as though entirely unincumbered by any litigation, existing or threatening.

Notwithstanding the fact that lawyers, accountants, and engineers frequently experience considerable difficulty in grasping the significance of each other's work and its technical exigencies, and frequently display a regrettable lack of sympathetic understanding when dealing with each other, it is unquestionably true that there is no possibility that good engineering or good accounting is not also good law. Unfortunately, the converse is not always true. If an engineer or an accountant bases his work upon concepts that run counter to the statutes of the courts—that is, to the "applicable law" —that work has no practical value. It is quite possible, on the other hand, for a particular approach to a problem to be very good law, good in the sense of valid, and at the same time to be very poor engineering, or accounting, or medicine. For example, it may be very good law to state than an operator or a royalty owner cannot claim as recovery from his tract any more than his appropriate percentage of the oil that is estimated to have been in place originally under the tract, but every operator knows, and every engineer knows, that from a practical viewpoint, wells on many tracts will certainly produce much more oil than originally underlay the tract. This may be due to a number of conditions, either physical or quasi-legal or both. It is common knowledge that wells drilled on the west side of the Oklahoma City field are draining restricted areas. For an engineer to omit this from consideration would be a "fatal defect," even if the Brown v. Humble decision meant anything in Oklahoma or if the Oklahoma City field were in Texas. In a field like East Texas, in which proration is chiefly on a per-well basis, allowables varying between very narrow limits, and the expulsive energy being supplied by water advancing from one direction, it is known that three wells will produce nearly three times as much oil as one well on an identical tract. Perhaps at some time in the future some one will shut down two of those wells, but on the other hand, maybe he will not, and the probability is that the wells will not be disturbed. This condition is of course recognized by the Commission's engineers and probably by its lawyers.

Whereas it might have been true in the case at bar that these particular wells were in imminent danger of being enjoined, it is an inconsiderately harsh criticism of the engineering report to designate the failure to mention this rather remote possibility as a "fatal defect." The "fatal defect," if any, lay with the registrant's lawyers. The engineer was quite within his rights in estimating that these wells would drain from neighboring lands, and would do so as long as they were permitted to continue producing. It was a lawyer's province to state whether or not there was a legal hazard in connection with them.

It should be borne in mind, however, that the quotations cited were all taken from a legal brief in support of a motion to issue a stop order. The whole document was frankly in advocacy of a definite purpose, and was in no sense intended to be an unbiased presentation of facts. That this harsh attitude does not reflect the official position of the Commission itself is shown by what follows. Greatly modified in tone is the language covering this point in the formal stop order release finally issued:

> "While it is true that the engineer is primarily concerned with the physical aspects of the properties rather than existing or potential legal restrictions upon production, the latter is obviously material to the investor. The engineer's report and estimate of production of the East Texas properties fails to give effect to the limiting rule enunciated in Brown v. Humble Oil and Refining Company, which was known or should have been known by the registrant. The use of these estimates in the registration statement and prospectus without appropriate qualification, in our opinion renders them misleading."

Although the last sentence seems to place the blame for issuing misleading statement upon the registrant rather than upon the engineer, there is no mistaking the thinly veiled criticism of the engineer. It is criticism of this kind from such a competent source that the engineer who values his professional standing will seek to avoid. In doing so he should not be called upon to prejudice the value of his work by making his report a catalog of every imaginable hazard that might now or in the future operate to curtail future production from the property.

The engineers for the Commission are fully aware of the irrelevancies to which a too rigid application of such refinements would inevitably lead, and, being technical men of wide practical experience in the oil industry, are not seeking to impose valuation methods that lead to absurdities or defeat their own ends. The best course for the engineer, if part or all of his estimate of future recovery is in excess of the remaining portion of the original oil content, would be to append to his estimate of future recovery, without comment, an estimate of the original content and the recovery to date. This would force the registrant's legal advisers to apply a discount factor commensurate with the risk of possible injunction against the complete recovery of the amount of oil forming the basis of value as determined by the engineer, and would place the responsibility for this distinctly legal feature where it properly belongs.

As a means of keeping abreast of the times in their profession no better suggestion can be made to engineers than to follow the S.E.C. cases, not in order that they may be able to avoid responsibility that properly belongs to them, but that they can obtain expert guidance in assuming such new responsibilities as changing conditions may properly lay at their door, and in protecting themselves from attack upon grounds with which they have no proper concern.

Analysis of Stresses in Hook-offs for Wells Pumped by Central Powers

Photoelastic study of scale models facilitates recognition of satisfactory design

By KENNETH N. MILLS*

As the depth of wells pumped by central powers has increased, more substantial types of hook-off devices have become necessary. The early hook-off devices performed satisfactorily on shallow wells pumped by a short-stroke power, but as the depth of wells and pumping stroke increased, they became less satisfactory. Some of the shortcomings of hook-offs of these early types were caused by improper application and could have been eliminated. Although some of these defects, e.g., lack of safety, lack of well pick-up, and unnecessary flexural stress, could not be eliminated without changing the design.

To overcome some of the disadvantages of the common hook-offs, the notched slide-bar hook-off was designed. The early models of this type hook-off were poorly engineered and did not realize their full potentialities. They did not provide well pick-up, they lacked desirable safety features, they were so made that the line of pull passed through the notches, disregarding the stress condition created, and they were improperly applied.

In order to determine the most efficient position of the line of pull relative to the center line of the notches in a slide bar a photoelastic study of several slide bar designs was made.

In this method of stress analysis, a beam of plane polarized light is passed through a model of the part in question. This model is made of an isotropic translucent substance such as celluloid. The polarized light passing through a celluloid model before any load is applied will show a rather dark gray image. If the model is a celluloid beam of constant bending moment, a series of parallel colored bands of light will be projected when the beam is under load. When the moment on the beam is applied, the extreme edge of the beam will project a yellow band. When the moment is increased, the yellow band will move toward the center of the beam, and in its place an orange band will appear. Further increase in the moment will cause the orange band to move inward and the edge to become red. This process will continue as the moment is increased, and the order of the bands from the center of the beam outward will be yellow, orange, red, violet, blue, green, yellow, orange, etc., to the extreme edge. If a photograph were made of this beam it would show a series of parallel, equally spaced black and white bands, as shown in Fig. 1.

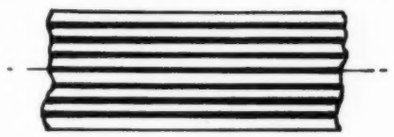


Fig. 1

The color and order of these bands have a definite relationship to the intensity of the shearing stress, and these colored bands are loci of points of equal maximum shearing stress. For this reason, these bands indicate the stress distribution in a body. From this information, points of stress concentration, therefore points of possible failure, can be determined and by a process of trial and error eliminated or modified.

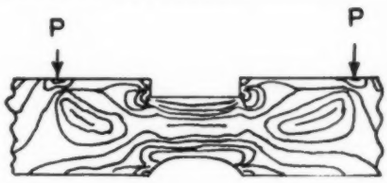


Fig. 2

For example, if a square and a rounded notch were cut in the foregoing beam these bands would arrange themselves approximately as shown in Fig. 2. As these bands indicate lines of constant shearing stress, it can be seen that the stress is concentrated around the corners of these notches and the points P where the load is applied. It also can be seen that the degree of stress concentration is greater in the corners of the square notch than in those of the rounded notch. From these observations it can be concluded that under a varying load, failure in this beam would start in one corner of the square notch.

The early slide-bar hook-offs employed slide bars designed as shown in Fig. 3. The line of pull coincides with the center line of the notches. This type of slide-bar loading induces unnecessary bending stresses in the slide bar, and unless the slide bar is made sufficiently strong to withstand these stresses, failures will occur under the notches.

Fig. 4 shows the results of a photoelastic analysis of this slide bar design. Note the crowded and sharply curved bands at the roots of the notches indicating points of high stress, therefore points of possible failure. Experience has shown that unless this condition is considered, and the bar rated accordingly, failure will occur at one of the notches.

A possible inversion of this early slide bar layout is shown in Fig. 5. In this design the line of pull is diagonal to the center line of the notches. The results of a photoelastic analysis of this design are shown in Fig. 6. Examination of this figure reveals that this design has no advantages over that shown in Fig. 3.

To obtain the maximum utility from the material used in slide bars, the next

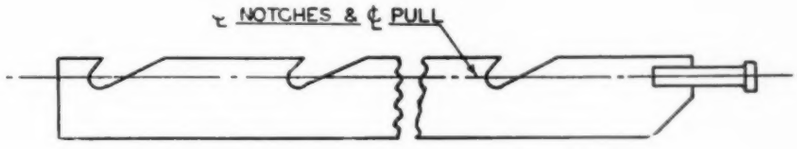


Fig. 3

*Chief Engineer, American Manufacturing Company of Texas.

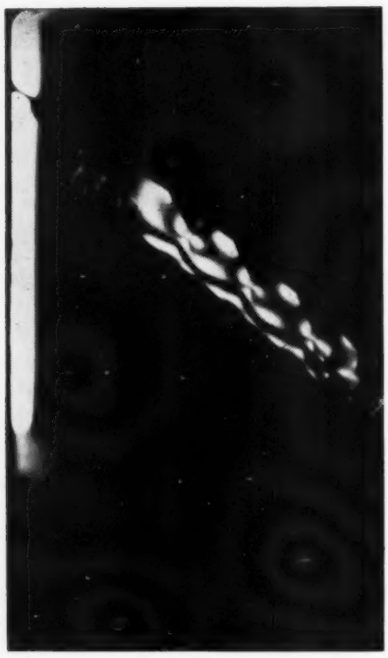


Fig. 4

step in their development has been to locate the line of pull in the solid section of the bar as shown in Fig. 7. A photoelastic analysis of a bar of this type, the line of pull located in the lower half of this section, is shown in Fig. 8. Examination of this figure reveals that only slight bending stresses are induced in the bar, and that the stress at the root of the notches is greatly relieved. Fig. 9 shows the results of moving the line of pull upward into the blank section of the bar. When this change is made all the bending stresses are removed, and the stress condition around the notches is good.

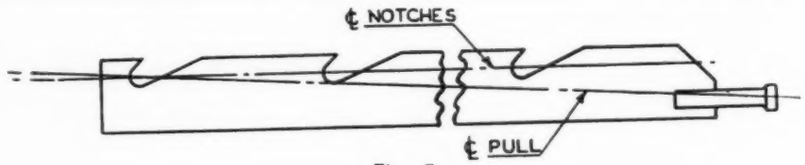


Fig. 5

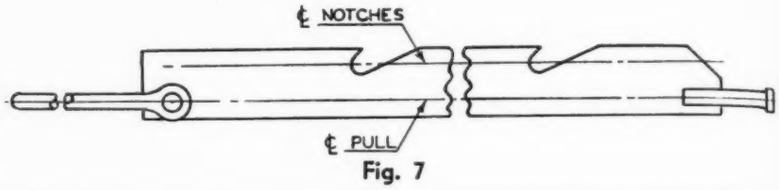


Fig. 7

When applying any of the above designs of slide-bar hook-offs to central powers, consideration must be given the flexural stresses induced in the slide bar by the lateral movement of the power disk. If sidewise movement of the slide bar is restrained at the hook-off post, a bending stress will be induced in the slide bar. This stress will be a maximum when the well is at mid-stroke. The stress produced in a slide bar when used on a power having a hook-off post that does not permit lateral movement of the slide bar can be found by one of the following formulas. This stress should be limited to 10,000 lb. per sq. in. for good slide-bar life. The dimensions not defined with the formula are shown in Figs. 10 and 11. All dimensions are in inches.

$$S = P\left(\frac{1}{A} + \frac{BR}{LZ}\right)$$

Where: S = Maximum combined stress

P = Pull rod pull at power

A = Net cross-sectional area of slide bar (total area less area cut for notch)

Fig. 6

$Z = \frac{MT^2}{6}$ = Section of modulus of net section of the slide bar around its vertical axis

T = Thickness of slide bar material.

If the line of pull coincides with the center line of the notches, the following formula should be used:

$$S = P\left(\frac{1}{A} + \frac{BR}{LZ} + \frac{N}{F}\right)$$

Where: S = Maximum combined stress

P = Pull rod pull at power

A = Net cross-sectional area of slide bar (total area less area cut for notch)

$Z = \frac{MT^2}{6}$ = Section modulus of net section of the slide bar around its vertical axis

T = Thickness of slide bar

$F = \frac{TM^2}{6}$ = Section modulus of net section of slide bar around its horizontal axis.

As several manufacturers are now offering improved types of common hook-offs featuring several desirable improvements in safety, data on their application will be found useful. In applying this type of hook-off the stresses in the section of pull rod passing through the post, induced by the lateral movement of the power disk, must be considered if successful performance is to be attained.

The maximum stress in the section of the pull rod passing through the post can be found by the following formula, and the stress should be limited to the maximum recommended by the pull rod manufacturer for the grade of pull rod used at this point. The dimensions not defined with this formula are shown in Fig. 13. All dimensions are in inches.

$$S = \frac{P}{A} + 1.5 = \frac{RED}{BO}$$

Where: S = Maximum combined stress

P = Pull rod pull at power

Fig. 8

A = Cross-sectional area of rod passing through hook-off post

E = Modulus of elasticity of steel = 29,000,000 lb. per sq. in.

D = Diameter of pull rod passing through hook-off post.

The above formula is true only when the following expression is satisfied:

$\frac{PB^2}{3EI}$ is greater than 0.999

Where: I = Moment of inertia for pull rod passing through the hook-off post

Table 1 gives the values of A and the term 1.5 R E D for a 36-in.-stroke power for pull rods of various sizes. Table 2 gives the values of the term 3E I for pull rods of various sizes.

Several types of power hook-offs are designed to withstand the adverse effects of the lateral movement of the rods. One of these devices, shown in Fig. 12, has a long horizontal slot in the hook-off post. It has a notched slide bar that travels sidewise in this slot, and the lateral movement of the rod line is absorbed in a rub post installed a short distance behind the hook-off post. The loads caused by lateral movement of the rod line are absorbed in the pull rod instead of the slide bar, thereby relieving the slide bar of stress. This device has all the desirable features of the slide-bar hook-off including well pick-up and its slide bar is not subjected to flexural stresses by the lateral movement of the rod line.

Several manufacturers offer the cross-head type power hook-off, one

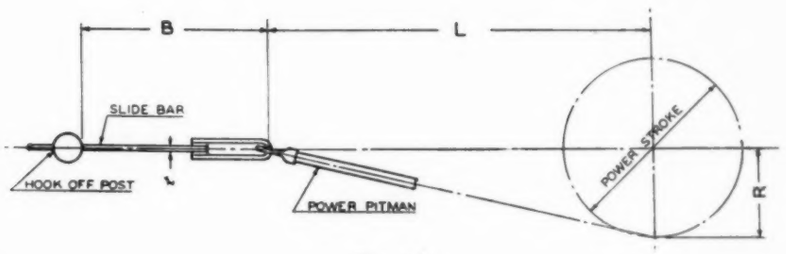


Fig. 10

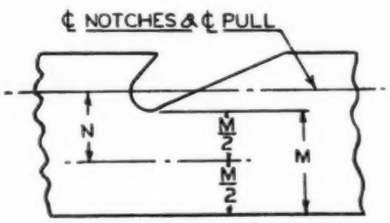


Fig. 11

TABLE 1

Rod diam., in.	Area	1.5 R E D
5/8	0.3068	488,000,000
3/4	0.4418	587,000,000
7/8	0.6013	685,000,000
1	0.7854	783,000,000

TABLE 2

Rod diam., in.	3 E I
5/8	652,000
3/4	1,350,000
7/8	2,501,000
1	4,270,000

Fig. 9

Fig. 12

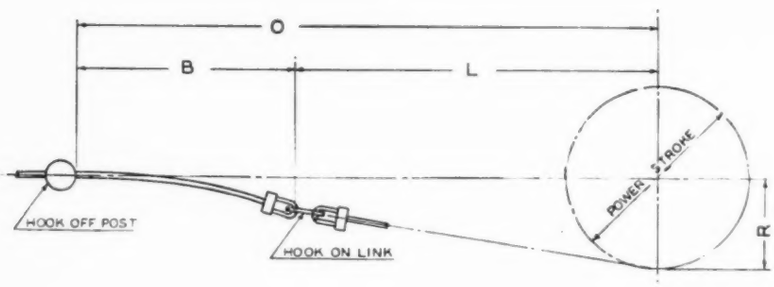


Fig. 13

ficiency of use of members, safety, serviceability, and cost, but the chief factor entering into the selection of a power hook-off is personal opinion of the relative importance of these various factors.

make of which is shown in Fig. 14. In this type power hook-off the power pitman connects to a link pivoted on a bearing on the cross-head, which is connected to the rod line. The lateral load created by the cross-head is absorbed by the cross-head guides without imposing unnecessary stress on any part of the hook-off mechanism.

As any type hook-off can be made sufficiently strong to perform satisfactorily on any well, regardless of depth, the fundamental differences between the various types of hook-offs are ef-

Fig. 14

Distance Checking of Boiler Pump Operation

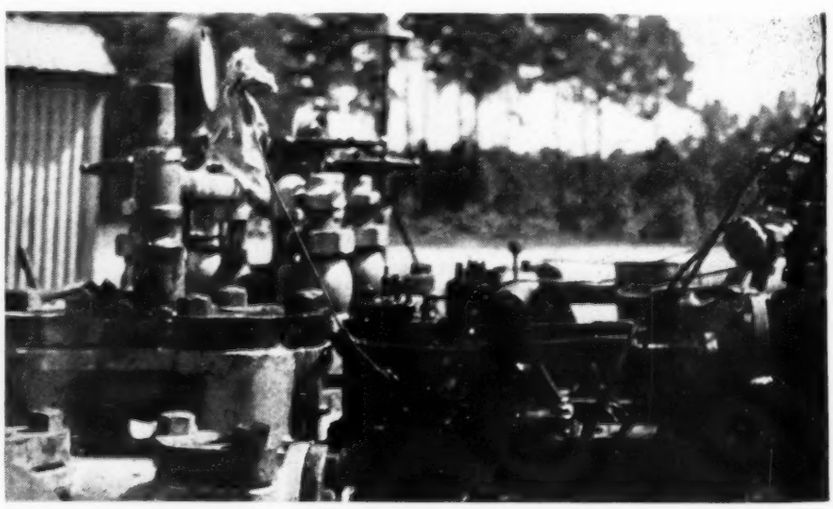
By CHARLES C. LYNDE

THE fireman is called to the derrick floor whenever an extra man is needed around the rig, but frequently it is necessary for him to make several trips between boilers and rig to observe the operation of the feed-water pumps.

One fireman devised a simple but effective means of observing pump operation from a distance. He fastened a white cloth to an extension of the lever operating the lubricator, which is direct-driven by one of the two pump rods through the valve gear. As the pump rod travels to and fro the same motion, magnified by the extension, is imparted to the flag.

Movement of the flag is readily visible from any point around the rig. By focusing the pump light so that the flag is illuminated the device is made to serve effectively at night.

In the photograph the flag appears to be in contact with the pressure gauge, but its arc of travel is actually two ft. nearer the camera than is the gauge.



Extension arm on lubricator drive carries flag visible from any point around the rig

Metals Used in Pipe Line Construction and Operation*

Part 2 (Concluded)

By LEWIS F. SCHERER
Assistant Chief Engineer, The Texas Pipe Line Company

Gate Valves

Gate valves form a very large part of the industry's investment. Almost all types of valves are, of course, used in some form or other, but we are here principally concerned with the gate valve as used in the main line, on oil tanks, in manifolds, and wherever stoppage or change of direction of the stream may become necessary. (Fig. 7.)

Essentially all makes are similar and the discussion will be one of general characteristics. The use of cast iron for the shell and bonnet and, in fact, all principal parts, is almost universal. This is primarily due to cast iron's high resistance to oxidation, which is one of a pipe line's greatest hazards whether buried or exposed. Valves must withstand extreme shock and tension and must meet internal as well as external corrosion. Valve shell metals must be, and are, therefore, improved mainly against oxidation on the outside, against corrosion and erosion on the inside, and against high shock and strain. For these purposes gray cast iron, as originally used, has been in service in oil lines for years.

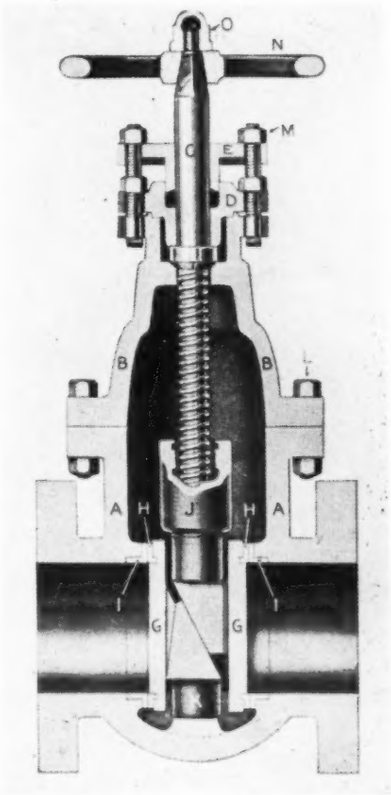
The tendency toward improvement during the last ten years has been to reduce the carbon content in cast iron for valve metals to produce a finer grain structure. Such metals are now often referred to as "semi-steel." Making a fine grain cast iron does not materially reduce the metal's resistance to oxidation and greatly increases its resistance to tension and shock. Reduction of the carbon, of course, necessitates adjustment of the phosphorus, silicon, and sulphur content.

Copper free "Ni-Resist" cast iron and nickel combinations containing less nickel than "Ni-Resist" and not copper free, have been developed that will increase the valve's resistance to oxidation and corrosion materially. Their greater present cost does not warrant their use except in rare instances. Research will no doubt develop a metal containing proper combinations of nickel that will enable the manufacturers to obtain the desired results without undue cost.

The problem in valve trim metals, mainly stems and seat rings, is considerably different from that of the shell. Failure of either interrupts the service, but the replacement costs of parts are small. Conditions to be met in trim metals are mainly corrosion from the fluid passing through the valve, resistance to abrasion and wear; and in the stem, greater tensile strength.

Seat rings are subjected to closing over sand particles and scale or other solids. Material that will "squeeze" is ideal to produce tight closing valves. Bronzes have been most satisfactory so far in pipe-line service. The life of seat rings seems to depend more upon the accident factor, i.e., the closing of the valve upon some substance that would destroy the seat. Of course, where valves are operated "pinched" erosion would be a factor, and where "sour" crudes, that is, crudes containing hydrogen sulphide or other corrosive agents, are handled corrosion becomes a factor.

Fig. 7. Section through gate valve



Manganese bronze stems give greatest satisfaction where a combination of wear, corrosion resistance, and reasonable tensile strength are required. In the larger valves operating under high pressure, steel stems are more desirable from a strength standpoint. The use of nickel or stainless steels is hardly warranted due to the greater cost.

Recently, the plug-type valve has come into considerable use in pipe line service. The remarks concerning gate valves will in general apply to the metals used in plug valves and it need not be discussed from that standpoint.

Maintenance of Mechanical Equipment

The problems involved in the maintenance of the mechanical equipment in pump stations are the same as those for like equipment in similar service. As brought out previously, however, there is one important difference, and that is that the operating time or "load factor" of pipe-line equipment is much greater than for other service, and the "standby" equipment available for use during repairs is usually limited. It is, therefore, the policy to aim toward greater life of wearing parts, keeping in mind availability of materials in making any repairs, change in design, or in specifications of a given part.

The principal items of pump station equipment to be given attention herein are Diesel and gas engines, reciprocating and centrifugal pumps, jacket-water coolers, and various pieces of auxiliary equipment. Owing to the rapidity with which it is becoming obsolete, we need give no space to steam equipment. Generators and motors as used by pipe lines are of standard design except that they are usually of vapor- or explosion-proof construction, so that the everpresent explosion hazard may be reduced as much as possible.

*Paper presented at the Western Metal Congress, Los Angeles, California, March, 1938.

Diesel Engines

Diesel engines constitute by far the greatest proportion of prime mover horsepower. In most essentials they are of commercial construction and are of all types, from the large slow-speed horizontal engine through low-speed heavy-duty vertical type to the modern high-speed engine. Each type uses metals of characteristics best suited to its service; however, pipe lines find some variations from standard practice to be advisable and it is these cases that we shall discuss.

Cylinder heads are often subjected to severe service conditions not always encountered in commercial practice. Conditions over which we have little control may necessitate protracted operation at high loads and excessive temperatures, or untreated cooling water may need to be used in an emergency, resulting in excessive scaling and eventual breakage. It has been found that by making slight changes in the head design, satisfactory cast-steel heads could be used with entire satisfaction. These heads also resulted in correcting weak design in the original cast-iron head without radical change in coring.

The long service required of our engines calls for special attention being given to the materials used in the pistons and liners. In this, the manufacturers give considerable co-operation. A service life of 80,000 hours is not unusual.

Liners are generally made of a close-grained gray cast iron produced by an approved process with a maximum phosphorus content of approximately 0.35 percent and maximum sulphur content of 0.11 percent. The hardness ranges from 200 to 260 Brinell with the tendency toward the higher Brinell but keeping always in mind that they must be machinable. A honed finish is desirable. The tendency for replacements is toward the use of electric furnace iron, and, as centrifugal cast liners in the larger sizes are made more readily available, more of these will be used.

A "semi-steel" cast iron has been found most desirable for use in pistons. Maximum phosphorus content is approximately 0.30 percent, and maximum sulphur content is approximately 0.10 percent. The hardness is usually somewhat less than for liners, being 200 to 225 Brinell. There is some tendency toward steel heads in the larger sizes but this is not general. Aluminum alloys definitely have not been found satisfactory in pipe-line service.

Instead of fuel oil, economics necessitates that Diesel engines in pipe-line service use crude oil for fuel. This fuel carries a relatively high percentage of abrasive and is often most corrosive. Such fuel results in special attention being given to fuel systems. Kansas and West Texas crudes give considerable trouble in this respect.

Many manufacturers supply hardened high-carbon steel plungers as original equipment in their fuel pumps and these corrode seriously in service.

Fig. 8. Valve plates destroyed by scale

Such corrosion results in failure of packing and excessive leakage. Various types of stainless steel were tried without material success due primarily to the inability to harden them sufficiently to withstand the service. A study of the physical characteristics of Nitralloy "G" showed that it could be surface-hardened to a high Brinell leaving a ductile center. The steel was also found to be resistant to corrosion. The first set of nitrided Nitralloy plungers have been in service approximately 10,000 hours without a single forced shut-down for repacking. From outward appearance, a service life of at least 40,000 hours is indicated. This compares with a record of 500 to 10,000 hours of service received from other materials tried.

Many of the engines in our service were originally equipped with close-grained cast-iron fuel pump bodies fitted with cold-rolled steel wing-type valves. The chemical content of the crude used as fuel caused the edges of the wing-type valves, as well as the valve seats, to corrode rapidly. Valves made of Tobin bronze and 18-8 stainless steel were tried.

It was found that whereas the Tobin bronze valves resisted the corrosive effects of the fuel better than the cold-rolled steel, the 18-8 stainless steel gave us a service life of 20,000 to 30,000 hours as compared to 3000 hours obtained from the original metal. The difference in cost is, of course, negligible.

The valve seats for these valves, being machined in the fuel pump body, were of cast iron and after approximately 15,000 hours were worn and corroded to the point where replacement of the entire fuel pump body at a cost of $40.00 became necessary. A machining practice was worked out permitting boring out these bodies and pressing in a sleeve of 18-8 stainless steel to form the valve seats at a cost of only $8.00. It was found that in addition to the saving in cost, the service life was increased at least 50 percent.

Fuel-injection nozzles in both solid and air-injection engines are a constant source of trouble and the solution of these difficulties is by no means complete. Nickel cast-steel injection needles have proven very satisfactory in several instances; nitrided steels are not particularly effective as they do not permit sufficient regrinding and trouble is experienced in the hardened surface failing from impact on the seat. Considerable success has been had with an injection nozzle, all parts of which were made of stainless steels having the following properties:

	Hardenable Percent	*Non-Hardenable Percent*
Carbon	0.30-0.40	0.08-0.20
Manganese	0.30-0.60	0.40-0.65
Phosphorus	0.30 Max.	0.10 Max.
Sulphur	0.30 Max.	0.15 Max.
Chromium	12.00-15	17.00-19
Nickel		7.00-9.00

These steels were used for the parts requiring specific properties and were heat-treated to give the desired hardness and tensile characteristics. They have increased the service life approximately 400 percent, but, as they are still under test, no positive conclusions can be given.

Various springs used throughout the fuel systems always give trouble, particularly where sour crudes are in use. Much work is still to be done in this connection. At present there are under test springs of various heat-treated carbon steels, stainless steel, and cadmium-plated music wire. No definite conclusions have been reached as yet. It is felt, however, that the stainless products would prove best if they could be obtained in a material of this type that would heat-treat consistently. We can only urge that metallurgists apply themselves to this and all other problems in connection with Diesel engine fuel systems.

Bearings and Bearing Metals

A discussion of the design of bearings and bearing metals would be much

too involved for this paper. Our efforts are bent mainly toward improving the pouring technique. We find that only the very best grade of babbitt will give us suitable service. We have had signal success recently in replacing bronze piston pin bushings with cast "Bronzoid," a high copper bearing metal having approximately the following properties:

Copper	70 percent
Tin	6 percent
Lead	24 percent
Yield point	16,140 lb.
Brinell	38
Tensile strength	26,367 lb./sq. in.
Elongation in 2 in.	12½ percent
Compression at 7500 lb.	None
Compression at 10,000 lb.	0.0008

It is claimed of this material that the special treatment to which it is subjected permanently arrests crystal growth in the lead.

The severe service conditions to which our engines are subjected, and the protracted periods over which they must operate without complete mechanical check, make it necessary that we pay particular attention to the fatigue of connecting-rod bolts. Some bolts that failed in this service were found to have been made of cold-rolled or carbon steels. These were replaced with bolts made of SAE 3140 steel heat-treated to give a tensile strength of 107,000 lb./sq. in. with an elongation in 2 in. of approximately 20 percent. There is every reason to believe that this material will give much greater life as there have been no failures or replacements. Manufacturers have now taken this into consideration and are supplying suitable material in current equipment.

Gas Engines

The remarks applying to Diesel engines may in general apply to gas engines in our service. However, the fuel problem is quite different. Gas engines operating on "sweet" gas require no special fittings or application of metals other than those supplied as standard equipment. Where "sour" gas is used, considerable difficulty is encountered in the corrosion of exhaust and intake valves and seats. The extensive use of gas engines in our service is relatively new, and the experimental work being conducted to combat the difficulties encountered has not advanced sufficiently to warrant definite conclusions at this time. Much work is being done in developing suitable valve seat inserts but thus far no satisfactory results can be reported on gas engines although there has been considerable success with inserts for small high-speed Diesel engines.

Positive Displacement Pumps

Large duplex and triplex horizontal double-acting reciprocating pumps are in most general use throughout the industry as repressuring units for the oil stream. Their design, operation, and maintenance provide many interesting problems from the metallurgists' viewpoint.

The principal problem in the design of this type of pump is the fluid end, which must have strength and great fatigue resistance, as it is operated under relatively high pressures and possibly under conditions of considerable shock over a long period of time. The manufacturers have solved this problem through the use of a good grade of cast iron or the use of forged-steel billets.

A cast iron that has been found most satisfactory has the following composition:

Silicon	1.5 percent
Sulphur	0.1 percent
Manganese	1.0 percent
Phosphorus	0.17 percent
Total carbon	2.5 percent

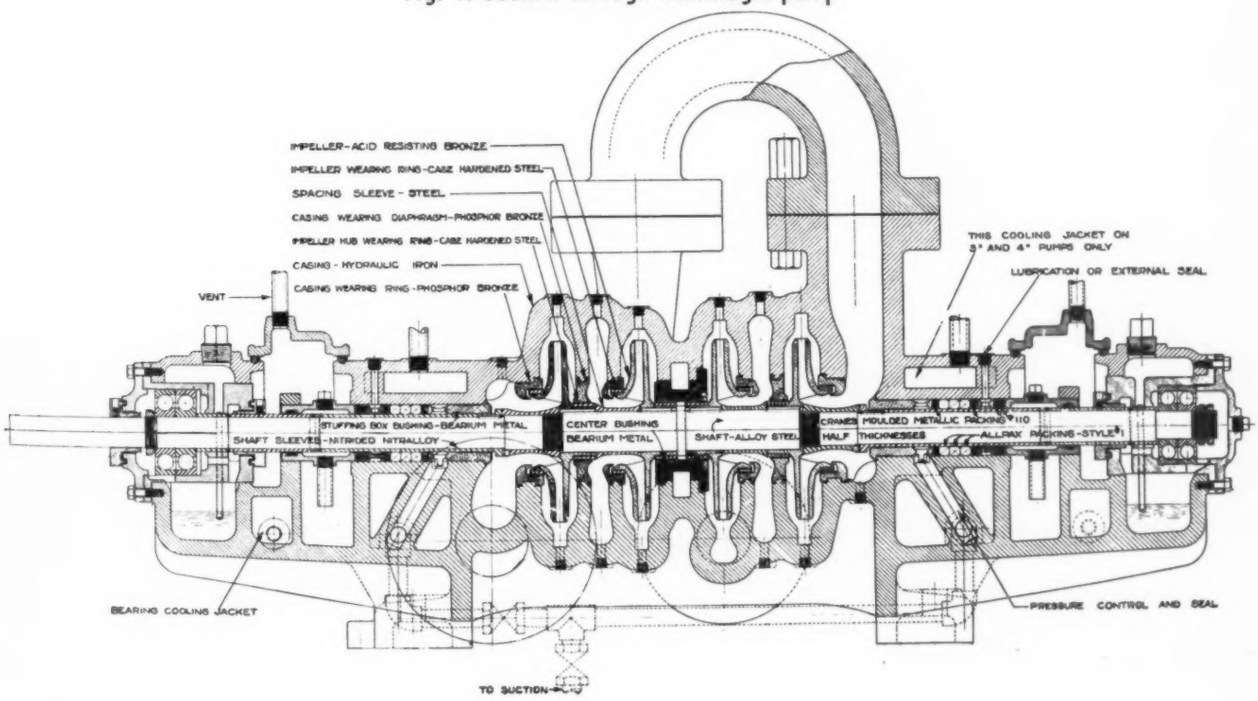
This metal will develop a tensile strength of 45,000 to 50,000 lb./sq. inch. It has a very high modulus of elasticity (25,000,000), and a high shock resistance and fatigue limit. It is readily machinable and has the peculiar property, for a cast metal, of freedom from segregation or porosity in heavy sections. This is probably due to the fact that it is a nearly eutectic alloy with a very narrow freezing range. The principal advantage of a chamber formed of this metal over one of a steel billet is the decided saving in cost.

The steel billet type of fluid end is machined from a solid carbon-steel billet having an approximate analysis of:

Silicon	0.2 percent
Sulphur	0.03 percent
Manganese	0.6 percent
Phosphorus	0.4 percent
Carbon	0.3 percent

The strength of a cylinder made of this material is in excess of any of the other parts of a pump, or the pipe line.

Fig. 9. Section through centrifugal pump



Its chief advantage is a greater resistance to shock. It also permits a much trimmer appearance for the finished product.

The metal used for plungers should be hard enough to withstand the cutting action of the sand and scale in the oil, should have a certain amount of resistance to corrosion, and the ability to take a fine finish grind, and take on a glaze or polish in service. In general, the same metal as used for cast fluid ends is supplied by the manufacturer for the plungers. Special service conditions may require the use of a somewhat higher carbon iron of the so-called "semi-steel" type, a typical analysis of which would be:

Silicon	1.25 percent
Total carbon	3.10 percent

(Other elements as in the above)

When the abrasive materials carried in an oil are unusually high, considerable success has been obtained with a patented high-carbon cast iron containing nickel. This material is ductile, has a fairly high Brinell, and takes a very high glaze in service. The life of plungers has been increased approximately 300 percent through its use.

The frames of these pumps are of necessity rather complicated castings with corners, ribs, angles, and reduced sections; so, to avoid possibility of cracks from cooling stresses, they are usually cast of a soft ductile iron having the following approximate composition:

Silicon	2.4 percent
Sulphur	0.07 percent
Manganese	0.6 percent
Phosphorus	0.3 percent
Total carbon	3.5 percent

To prevent frame stretch when the pump is in operation, it is necessary to reinforce it with steel tie rods, preloaded where possible, so that the frame will always be under compression.

The suction and discharge valves in the fluid end of these pumps form the balance wheel of the pump. A good valve is often the difference between a good pump and a poor one. Valves are of the ball, disk, or wing-guided type, and are of many different makes and a wide variety of designs. The major factors to take into account in choosing a valve for use in a pump are strength, performance or pump efficiency, service life, economy of operation, and initial cost.

A valve must be designed strong enough to withstand the pressures and shocks to which it is subjected. The ratios between seat area, lift, and free flow must be adhered to lest efficiency suffer. A valve may be strong and have a long service life, yet will be of little use if there is too much resistance to fluid flow, or too much slippage. Length of service is of importance because, aside from the expense of frequent replacement, consideration must be given the importance of shut-down time of the unit. Economy of operation depends, of course, upon how well the first three factors have been met. Obviously a valve that performs efficiently, and has a service life of two or three times as much as another, is a more economical valve. It is also true that an inefficient valve will result in excessive slippage, causing more work to be done by the prime mover. The first cost is, and should be, the least important factor. It is readily possible to spend several times the first cost of a good valve by purchasing several replacement sets of mediocre valves.

Due to the sand and scale that may be carried in crude oil the valves are subjected to excessive scoring action and abrasion. Where sweet crudes are handled, we have had considerable success with a fairly wide-faced manganese bronze wing-type valve of the following analysis:

Copper	68 percent
Zinc	22 percent
Manganese	3 percent
Aluminum	5 percent
Iron	2 percent

The tensile strength of this material is approximately 100,000 lb./sq. in. and its elongation in 2 in. is approximately 15 percent. The high strength, hardness, ductility, and fair degree of corrosion resistance make this an eminently satisfactory material. The width of face, necessary in anything except an extremely hard metal, leaves an appreciably unbalanced area, which means that to open such a valve against 750 or 800 lb. requires a momentary pressure considerably in excess of this in the chamber. This gives rise to an undesirable valve pound.

This same fault may be found with a ball valve, although of recent years there has been made available a hollow ball valve whose operation in this respect is much better. In general, ball valves in the sizes required are most unsatisfactory, and their use has been almost entirely discontinued.

Valves faced with No. 6 Stellite or similar material have overcome many valve troubles, but their use has not become general because of the welding technique required for the material's application. The heat of application also destroys the heat-treatment originally applied to the body of the valve.

A valve should be similar to any other piece of machinery, i.e., the part most subject to wear should be readily replaceable. There are on the market several valves of this type in which the disk or face is made of "Bakelite" or some similar substance, or of carburized nickel steel. The valve is so made that this part may be easily replaced after showing wear. Such a valve has all the advantages of a one-piece valve, and but few of its disadvantages.

The industry has had considerable success with this type of valve fitted with a flat-faced "Bakelite" insert with cap and guide made of SAE 3115 or 3140 steel, heat-treated to a Brinell of

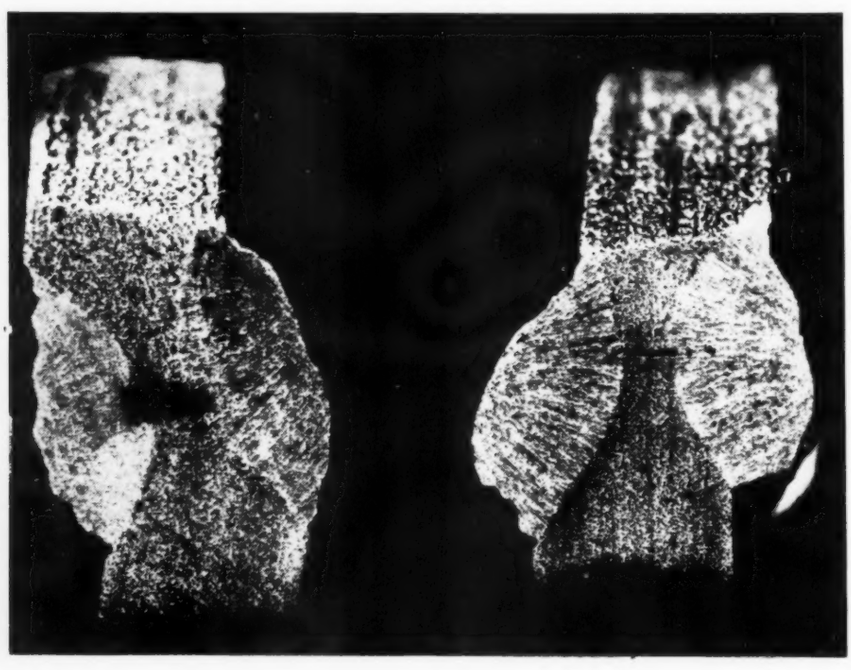


Fig. 10. Specimens of butt welds

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approximately 350, working on a replaceable steel seat of SAE 3115, 3110, or 4115, carburized to a Brinell of approximately 600. Such a valve has been found to have all the necessary advantages and the added advantage of considerably greater resistance to sour crude than most all-metal valves. Its action is very smooth, the wing guide may be designed to give any degree of rotation desired (a most desirable attribute that aids in keeping the seat clear and the wear minimized), and ample area can be allowed through the seat for the flow of fluid.

The wedge-adjusting bolts, as used for the cross-head and crank-pin bearing of most of these pumps, were usually made of ordinary carbon steel. These bolts are subject to extreme stresses in shear and in tension, especially if the bearing becomes slightly loose. Their life is being increased from 2,500 hours to 14,000 hours through the use of SAE 3140 steel.

Pipe Line Centrifugal Pumps

The use of multi-stage centrifugal pumps for main line pipe-line service is a development of the last ten years; in fact, they have only been in more or less general use since 1930. When not motor driven, they are powered by Diesel or gas engines whose speed is stepped up to the pump speed of 1800 or 3600 r.p.m. through the use of speed increasers. Originally they were virtually no different than high-pressure boiler-feed pumps; however, pipeline service showed that many changes were necessary to their most efficient and trouble-free service.

The casing of a centrifugal pump must be machinable in fairly light sections. The diaphragms between the stages must be rather thin to hold shaft length to a minimum, and yet these diaphragms must be bored to a very accurate dimension.

A casing must be strong enough to be safe when operating at a pressure of 800 to 1000 lb./sq. in. and must be stiff enough to permit no deflections of appreciable magnitude. It must be dense enough to prevent any "sweating" between stages. A very suitable iron for this service has the following properties:

Silicon	1.4 percent
Sulphur	0.07 percent
Manganese	1.0 percent
Phosphorus	0.3 percent
Total carbon	3.35 percent

The foundry problem in so intricate a casting is of primary importance as the metal must strip from the sand cleanly. The waterways must be smooth as some of them are of such shape as to be reached with difficulty for hand smoothing.

The impellers are ordinarily cast of a leaded phosphor-bronze as this metal casts readily, leaving a smooth surface. It has a high degree of corrosion resistance. An approximate analysis of such a bronze would be:

Copper	75 percent
Lead	15 percent
Tin	10 percent

These impellers usually carry replaceable steel wearing rings both at the eye and at the hub for increased wear resistance, and to make it possible to renew the necessary close running clearances when wear does occur. The casing rings are usually of the same material as the impellers, and are also readily replaceable.

Shafts and shaft sleeves present perhaps one of the most difficult problems encountered in the use of these pumps. Admittedly the method of installation and care of packing has a great deal more to do with the life of the shaft than does the material of which it is made. Some of the earlier pumps were not fitted with sleeves and wore excessively. Repairs were made by replacing the shafts or designing sleeves to fit. Recently some success has been had with building up the eroded portions by welding with a carbon-steel rod, producing a Brinell of approximately 300. This cannot be done more than twice, however, as the heat of welding changes the crystalline structure of the parent metal, resulting in failure.

All later design pumps are fitted with shaft sleeves through the stuffing boxes. These sleeves must be hard to resist the wear caused by sandy oil and incorrectly-adjusted packing. They should also be corrosion-resisting. Nitralloy possesses the required hardness when heat-treated, but its case is quite thin and it has little resistance to corrosion. A carbon steel with a deep case is ideal, but rusts easily. If it were not for the unreliability in the hardening of the so-called "hardenable stainless steels" they would be ideal in all respects. Stellite has been used with success, but it is a very poor bearing material, and gives packing trouble. Much experimentation is still being done on this problem of suitable material for shaft sleeve; its importance cannot be minimized. One interesting trial is being conducted with a high-chromium steel, centrifugally cast and hardened after machining.

Shafts were originally made of a carbon steel, but present practice calls for a shaft of highly alloyed, heat-treated, and thoroughly normalized steel. The long span between bearings, weight of the rotating parts, and the high speed all combine to make this most important.

Anti-friction bearings are now used almost exclusively, and their materials need no discussion here. They are readily replaced and a failure merely calls for replacing the bearing with a new part. If this type bearing could be successfully manufactured of corrosion-resisting material it would find more ready application to pipe-line service.

Centrifugal jacket-cooling-water pumps are usually standard bronze fitted, except that it is now common practice to specify that the shaft and wearing rings be of monel metal.

Jacket-Water Coolers

Many means are used to cool the engine jacket water, but of recent years it has become quite common practice to use shell-and-tube type heat exchangers. These exchangers utilize the relatively cool stream of oil handled by the main line pump to cool the jacket water, the oil passing through the tubes and the water through the shell. Such equipment, being at the time of first adoption a radical departure from common practice, required development and provided some interesting chemical and metallurgical problems both in the exchangers and in the engine jackets.

Water systems of this type are generally operated "closed" with a vent to atmosphere. It is well known that dissolved oxygen in water attacks iron to form ferrous hydroxide. The initial attack may be due to pure chemical action, or to small galvanic currents caused by variation in the iron structure. Once started, there is a definite local galvanic action that causes pitting. This action may be controlled by keeping the water alkaline by chemical treatment, and adding sodium sulphite to react with the dissolved oxygen to form sodium sulphate. This treatment is effective so far as the heavy castings and piping are concerned, but is not always effective in protecting the thin wall tubes of the exchangers.

When exchangers first came into general use for this service, it was thought that most of the trouble would come from the oil side; however, quite the contrary was soon evident. As soon as trouble developed in an exchanger, it was retubed with Admiralty metal. The use of this metal was not only much more expensive but it was soon found that the problem of dezincification had to be considered.

Recent experiments by oil refineries have shown that the use of red brass offers considerable advantages. It is generally understood that a metal of approximately 85 percent copper offers the greatest resistance to corrosion by

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. . . but, whatever you choose to call it . . . when the "old standard rig", with all its inefficiency and costly maintenance, is moved out and **trouble-free, efficient** LUFKIN PUMPING UNITS are moved in, a real, progressive step in the right direction has been taken.

This major oil company is replacing eighty-five "standard rigs" with LUFKIN UNIVERSAL UNIT ASSEMBLIES.

LUFKIN PUMPING UNITS

LUFKIN UNITS are manufactured in Lufkin, Texas, by the Lufkin Foundry & Machine Company. Branches in principal oil centers

water. New exchangers for pipe-line work are now generally specified to be tubed with a brass having the following composition:

Copper	85 percent
Zinc	15 percent

This seems to be an ideal combination, and although exchangers tubed with this material have hardly been in service long enough for any definite conclusions to be reached, high hopes are held for their success.

When it is realized that one pipe line company alone operates more than 75,000 sq. ft. of shell and tube exchangers the importance to the industry of protecting this investment becomes obvious.

Tankage

Pipe line companies naturally require considerable tankage for their operations. The size of this tankage varies from a capacity of a few barrels to tanks of 140,000 barrels. No particular metal problem is involved except where the tanks are in sour crude service. It then becomes necessary to combat corrosion caused by salt or acid water in the bottoms and corrosive vapors acting on the underside of the roofs. Some of these problems are solved by mechanical means, such as floating roofs, or flat submerged roofs. Others are solved by the use of special metals.

Where resistance to corrosion must be considered, use is made of copper-bearing steel pipe for swing pipes, "Korodless" wire cable for lifting the pipe, cast-iron conservation vents or all-aluminum vents, both with aluminum valves and cages, and other fittings and appurtenances of aluminum. Because of the large tonnage of metals involved, it would not be practical to apply corrosion-resisting metals to the roofs or shell plates of the larger tanks. Small lease or field tanks are sometimes made of wrought-iron plate with considerable success. The use of this material for the bottoms and roofs only is of considerable advantage on somewhat larger tanks. Although it is not yet readily obtainable, recent developments in heavily-plated steel plate, or plate rolled with a sheet of stainless steel fused to one side, will no doubt be a great stride forward.

Of recent years the use of welding in the construction of the larger size tanks has become quite common. Many of the problems involved in the welding of steel line pipe are common to this practice; however, the greatest difficulty to be overcome at this time is the welding technique and the difficulty of readily detecting poor welds. Fig. 10 shows two coupons cut from a butt-weld seam on a 55,000-bbl. tank. Visual inspection did not show them to be the poor welds they obviously are. It is the possibility of welds such as these passing the inspector's attention that has held the oil industry back from general adoption of this type of construction even though it offers so many advantages over the old form of riveted construction.

Conclusion

We, in the pipe-line business, are particularly interested in the development of welding practice as applied to our problems and would welcome some means that would assure us of obtaining a 100-percent weld, not only in the pipe as now used, but in pipe of a higher carbon content. A means of readily determining a poor weld by some simple and economical device or test would also find ready acclaim. The problems induced through the handling of "sour" crude, that is, crude containing sulphur or some other corrosive agent, can all probably be solved by the proper application of special metals and alloys. Mechanical weaknesses and deficiencies can also be corrected through the application of suitable metals.

Naturally in a paper of such scope, we have been unable to discuss many of the interesting problems involved in the multitude of auxiliary equipment that the industry operates. It is sincerely hoped, however, that a clearer conception of the variety and type of problems with which we must cope may result in a closer cooperation between the manufacturer of equipment, the producer of metals, and the consumer of the mechanical equipment discussed. Much progress has been made, but this has been due to the efforts of a relatively few designers and pipe-line engineers, as the need of special consideration has not been generally made known.

Acknowledgment

Acknowledgment is made various manufacturers and their representatives for information supplied on their respective products. Acknowledgment is also made to the engineers who supplied their operating information and assistance in the preparation of this paper.

(EDITOR'S NOTE: The two photomicrographs shown in Fig. 4, Part 1 of this article, published in September, should have been turned clockwise 90 deg. to convey the proper meaning.)

Study of Patents Pertaining to Cracking

DAVID McKNIGHT, JR., Bureau of Industrial Chemistry, University of Texas, has published the results of a five-year study of the patents pertaining to cracking processes and methods, apparatus, and products.[1]

The history of the development of each of the better known cracking methods is traced through the basic patents on which each is established. Thus treated in detail are the Burton, Dubbs, Cross, Holmes-Manley, and Tube and Tank methods. In less detail the less well known methods are discussed, including the Fleming, Jenkins, Donnelly, Isom, and Bell liquid- or mixed-phase methods and the De Florez, Gyro, T. V. P., Clark, Leamon, Pratt, and other vapor-phase processes.

The essential features claimed in the more important patents are indicated and the distinctions between various methods are emphasized. Analyses of the court records of patent infringement suits are included.

The parts of the report thus far mentioned, constituting more than 100 pages of text and illustrations of a technical nature, provide in an easily understandable form an outline of each of the cracking processes.

After the technical discussion the report includes some pertinent comments of an unprejudiced observer upon the present situation as regards the holding of patents. The alternating series of hostile and conciliatory actions exemplified by the infringement suits and pooling of patents are outlined and the ultimate result indicated. That the apparently unavoidable and presumably legitimate monopoly has already been established seems evident from a study of the present structure.

The rights of the public and of the companies holding patents are stated and the defects in the present patent laws are indicated and possible corrective amendments suggested.

Part 2 of the report, pages 135 to 627, includes a catalog of all patents on cracking issued by the United States Patent Office, including date of issue, patentee and assignee, and subject matter. Reissued patents are listed separately. An index of patentees, an index of assignees, and a tabular summary of patent litigation complete the treatise.

[1] A Study of Patents on Petroleum Cracking with Special Reference to their Present Status, University of Texas Bulletin No. 3831, Austin, August, 1938. 627 pp. Price $3.00.

The hard, heavy hauling jobs in the oil industry go to International Trucks. The Olson Drilling Company relies on these powerful trucks to get their equipment through to location as this picture in one of their camps indicates. International Six-Wheelers (see truck in foreground) are famous in the fields for their work.

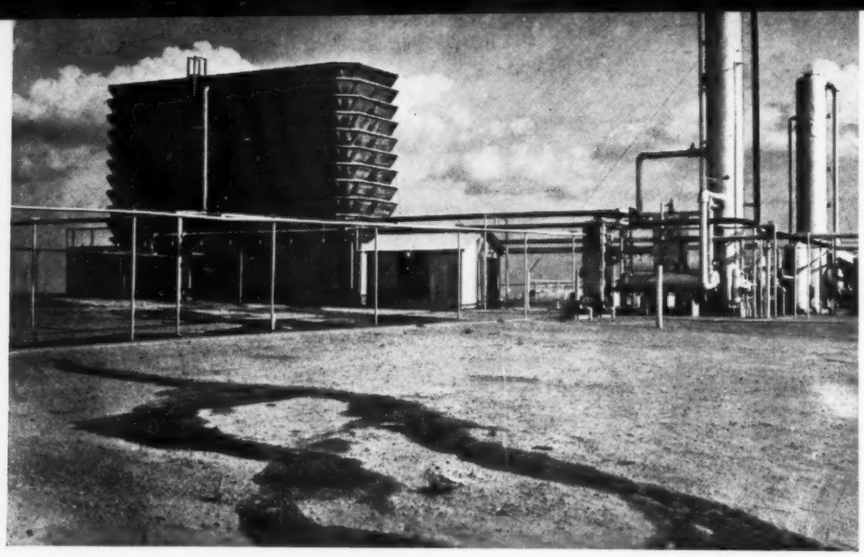
The Tougher the Job the Greater the Need for INTERNATIONAL TRUCKS

International Trucks long ago proved they can take a lot of punishment. The *quality* International Harvester builds into them shows up to the user's advantage in oil-field and other tough hauling. The investment you make in Internationals *pays dividends* in economy of operation and maintenance, dependability, and long life. Time alone has not built the reputation and preference for these trucks—*performance per dollar* has been the answer. Today Harvester experience and high-grade workmanship are available in 30 models and 99 wheelbases — ranging in size from Half-Ton Pick-Up Trucks to powerful Six-Wheelers. Turn your hauling over to Internationals —select your trucks from this broad line and solve your hauling problems the most satisfactory way. See these trucks at the nearby International dealer or Company-owned branch showroom.

An International Six-Wheel Truck owned by C. L. Tyrrell, contractor at Chase, Kansas, moving a cracking tower a distance of 100 miles. This unit and two other International winch-equipped trucks also lowered and raised this 80-foot tower. Mr. Tyrrell operates 15 Internationals.

INTERNATIONAL HARVESTER COMPANY
(Incorporated)
180 North Michigan Avenue **Chicago, Illinois**

INTERNATIONAL TRUCKS



Skelly Oil Company's Watkins Gasoline Plant

Large percentage of propane efficiently extracted from gas in Texas Panhandle plant

Natural Gasoline Vapors from Fractionator-Still Are Cooled By Air in Pre-Cooler

CONSTRUCTION of Skelly Oil Company's Watkins gasoline plant on the Watkins Ranch east of Borger, Texas, was begun on May 1, 1937, and the plant was placed in operation on July 17. Its rated capacity is 6,000,000 cu. ft. of gas per day. Gas is obtained from 227 wells, most of which are southwest of the plant. The gathering lines are connected to the flow tanks and separators and the gas passes through 44 field meters.

The plant is the absorption type, 11 single-cylinder, horizontal, 80-hp. gas engines driving the compressors that compress the gas to the 45-lb. absorber pressure from the intake pressure of atmospheric to 15-in. vacuum.

Maximum production is 15,700 gal. per day of natural gasoline of approximately 99-deg. A.P.I. gravity having a Reid vapor pressure of 59 to 60 pounds. All possible gasoline fractions are absorbed, including a large percentage of propane. Analysis of the residue gas is as follows:

Constituent	*Percent*
Methane	60.6
Ethane	23.4
Propane	16.0
Butane plus	0.0

Gasoline content of the wet gas ranges from three to seven gal. per M cu. feet. The oil produced by the wells from which the gas is obtained differs from that produced in other parts of Hutchinson County but its gravity ranges from 45 to 48 deg. A.P.I.

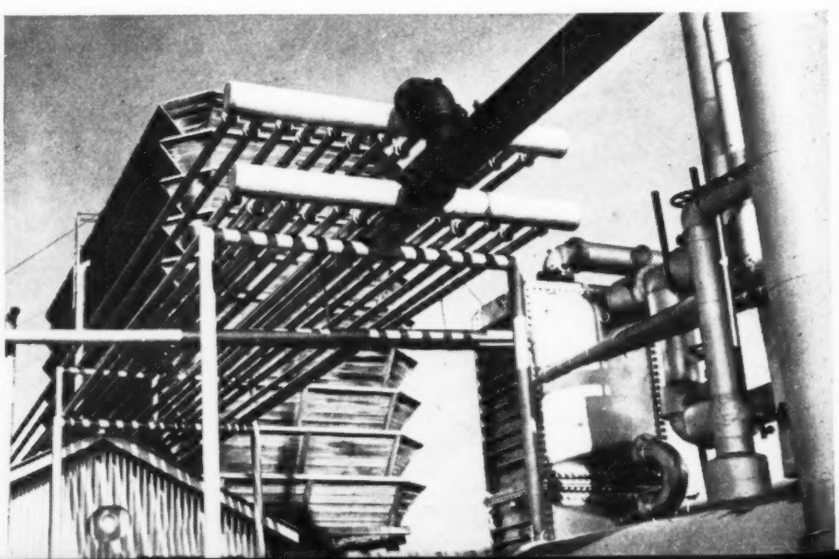
About 50 gal. of absorber oil per M cu. ft. of gas is circulated through the single absorber by pumps driven by electric motors. Current for the motors is generated in the plant by two 200-kw., 440-volt, a-c. generators.

A single still is used to fractionate the product. Vapors leave the still at a temperature of 204 deg. fahr. and pass through a double-bank air-cooled pre-cooler that reduces the temperature 10 or 15 degrees. The load on the atmospheric coolers in the louver tower is thereby reduced and as a result there is less scaling of the louver tower. The air-cooled pre-cooler consists of two banks of thirteen 2-in. pipes each, connected by lip unions to threaded nipples welded to the 6-in. headers. Two joints of 2-in. pipe are welded to form the 40-ft. cooling tubes. A rack made of 2-in. pipe supports the cooler and prevents vibration and misalignment.

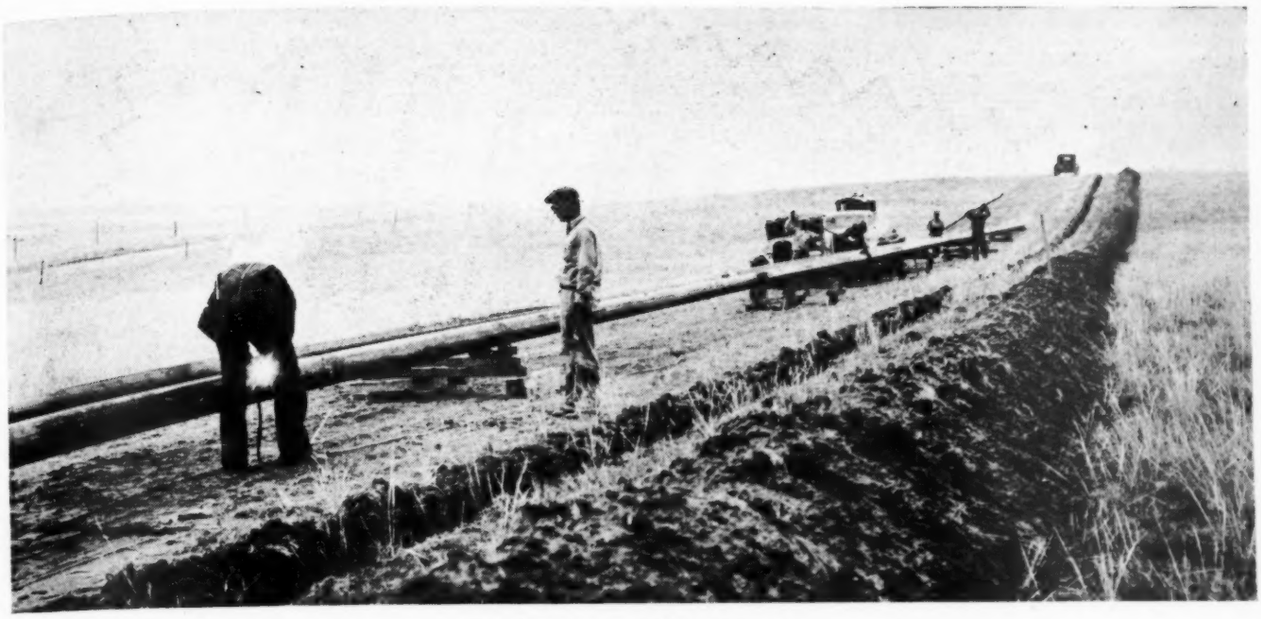
Although no gas is processed on Sundays, because of the Texas field shut-down, the absorber oil is circulated and the still is fired in order to maintain the plant in readiness for resumption of operation on Mondays.

The gasoline manufactured at the plant is piped 15 miles to the Shaffer Ranch plant at Skellytown, where it is fractionated into various products prior to shipment. The welded pipe line consists of approximately seven miles of 2-in. pipe and eight miles of 3-in. pipe.

Roy E. Bullick is plant superintendent and resides at Whitedeer, Texas.



Sections of air coolers on vapor line from still to louver tower



A "firing-line" welder at work

Construction Features of Pipe Line in Rocky Mountain Area

Much of the trunk system from Lance Creek Field, Wyoming, is laid through country of rugged topography

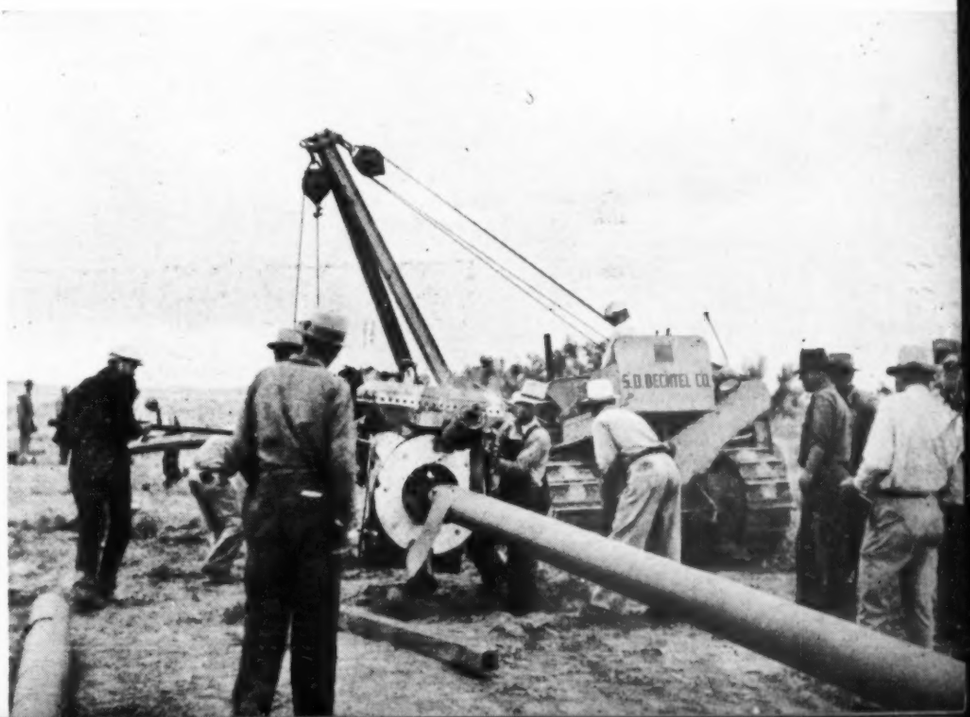
By FRANK H. LOVE

THE extensive trunk pipe line system being constructed by the Rocky Mountain Pipe Line Company, subsidiary of the Continental Oil Company, from the Lance Creek field, Wyoming, is expected to be completed by November 1st, giving that area a much-needed pipe-line outlet. Heretofore crude oil has been transported from the field only by tank car. Favored by weather conditions exceptionally fast laying time has been possible.

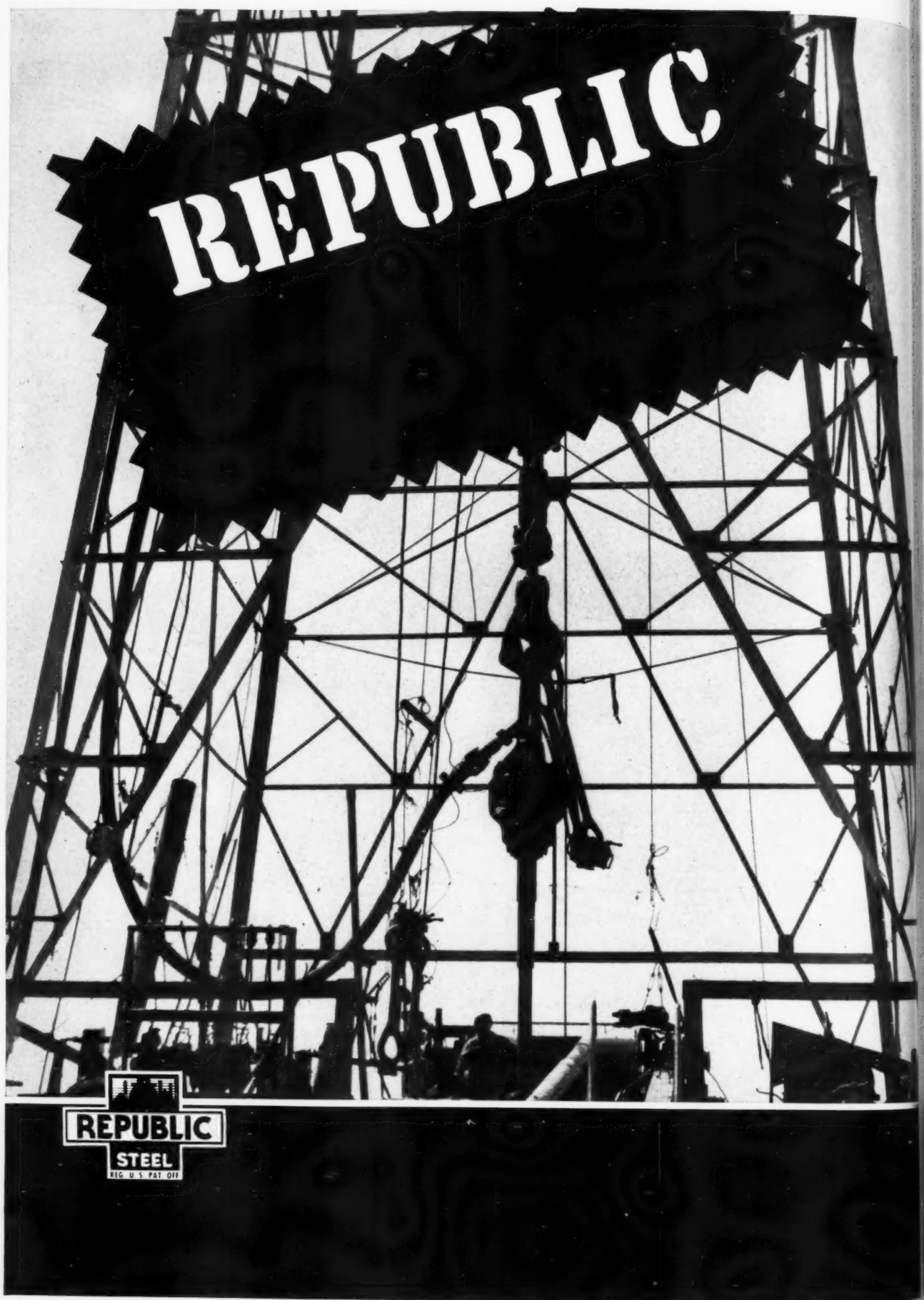
The system from Lance Creek to Cheyenne, of 8⅝-in. pipe, is being laid under contract by the S. D. Bechtel Company, the electric welding being done by the H. C. Price Company, Bartlesville, Oklahoma. The total length of this section of the line is 136 miles. From Cheyenne to Denver, a distance of 96 miles, the line is of 6⅝-in. pipe, the Osage Construction Company having the contract. The total distance of the line from Lance Creek to Denver is 232 miles. In addition a combination 4-in. and 6-in. line is being laid from Lance Creek to Glenrock, Wyoming, where the Continental Oil Company has a refinery.

The 96 miles of 6⅝-in. O. D. pipe is of seamless stock having plain ends and weighing 17.02 lb. per foot. Approximately 75 miles is being coated with No-ox-id, a chemically compounded grease-type rust preventive, and wrapped with asbestos wrapper impregnated with the same compound. The 8⅝-in. pipe weighs 25.29 lb. per ft., and of the 136 miles of this diameter pipe laid about 70 miles will be

(*Continued on Page 47*)



Machine used to coat and wrap in one operation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BERLOY* STEEL SHELVING BINS AND LOCKERS

REPUBLIC SHEETS, LIGHT PLATES AND ROOFING PRODUCTS

REPUBLIC WOVEN WIRE FENCING BARBED WIRE AND STEEL FENCE POSTS

TONCAN* IRON CULVERTS AND SECTIONAL PLATE PIPE

TONCAN* IRON ENAMELING STOCK
(for service stations)

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Guiberson Type A-1 Floor Block, on Kansas well, installed in derrick corner by means of special clevis assembly. Clevis is open at bottom permitting it to be easily installed over an eye bolt or cable loop.

On a Major Company's Well, near Wink, Texas, this Guiberson Type A-1 Floor Block is attached to an extension from the pulling unit by means of regular floor plate assembly. Can incline 45 degrees either way.

Showing How Guiberson Floor Block leans toward the novel, efficient pulling unit at correct angle when load is applied. Block won't fall down when line is slackened.

This Guiberson Store (below), at Kermit, Texas, carries stocks of Guiberson Swabs, Packers, Catchers, Floor Blocks, Drilling Heads, Oil Savers, Spiders, Rotary Pumps.

GUIBERSON FLOOR BLOCKS SAVE TIME AND TROUBLE

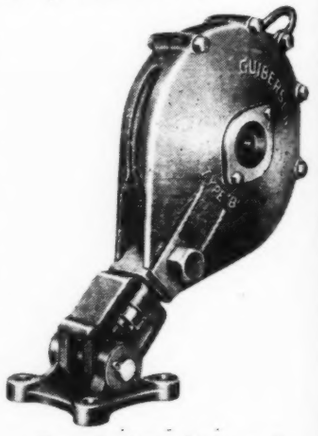
BECAUSE they are easy-to-install and easy-to-handle, Guiberson Floor Blocks save time and trouble. These blocks can be installed in the derrick corner by means of a special clevis assembly—or can be mounted on floor or extension from pulling unit by means of regular floor plate.

To facilitate handling, Guiberson Floor Blocks (1) have loops at the top; (2) have frames open at lower end, permitting block to be set over hoisting line without threading; (3) are designed, when used with floor plate, to permit a lateral movement of 45 degrees each way from vertical, which allows block to lean toward pulling unit at correct angle and prevents block from falling when line is slackened.

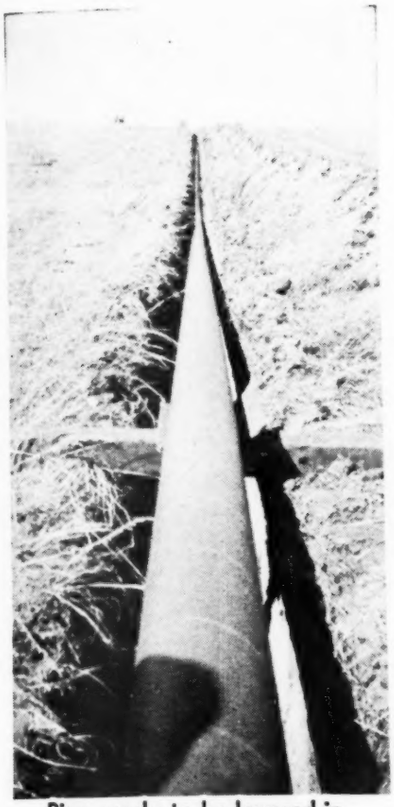
Guiberson Floor Blocks have two heavy-duty tapered roller bearing assemblies, easily adjusted from the outside. Center pin and bearing assembly are a self-contained unit, and bearing adjustment is unaffected by any distortion in frame. Frames and sheaves are cast steel (S.A.E. 3135).

There are two types of Guiberson Floor Blocks. Type A-1 has 16¼" O.D. sheave with ⅞" machined groove. Type B has 22" O.D. sheave with 1" machined groove. Frame of Type B is in two halves, forming safety guard around sheave. Capacities ample for wells of any depth.

See these blocks at your supply store, or refer to 1938 Composite Catalog, pages 804-805. The Guiberson Corporation, Box 1106, Dallas, Texas. Export representative: I. Frank Brown, 30 Rockefeller Plaza, New York City.



Type B with safety guard.



Pipe ready to be lowered-in

(*Continued from Page 43*)
coated and wrapped with the material mentioned.

Before construction work was begun soil tests were made and it was determinded that this amount of coating and wrapping would provide for all "hot spots," the rest of the pipe being laid bare except for the mill paint.

Lack of roads was the principal difficulty encountered in stringing pipe. In many places there were no roads whatsoever and in others only dirt roads, which at times were almost impassable. The entire right-of-way between Manville and Cheyenne was virtually without roads. Pipe was shipped by rail to Manville, Chugwater, Cheyenne, Denver, and Greeley, and from those points strung by trucks equipped with boom and winch.

Almost all types of country is traversed by the line's right-of-way, from flat table lands to mountains. Much of the line is through beet and alfalfa fields, but most of it is across valleys and over mountains. Cultivated fields at times presented difficulties because of irrigation ditches and considerable blasting was necessary in the rocky areas. At Goshen Hole, about 12 miles east of Wheatland, abrupt cliffs and almost solid rock, made work especially difficult. Similar conditions also were encountered at Big Hill and Sunrise.

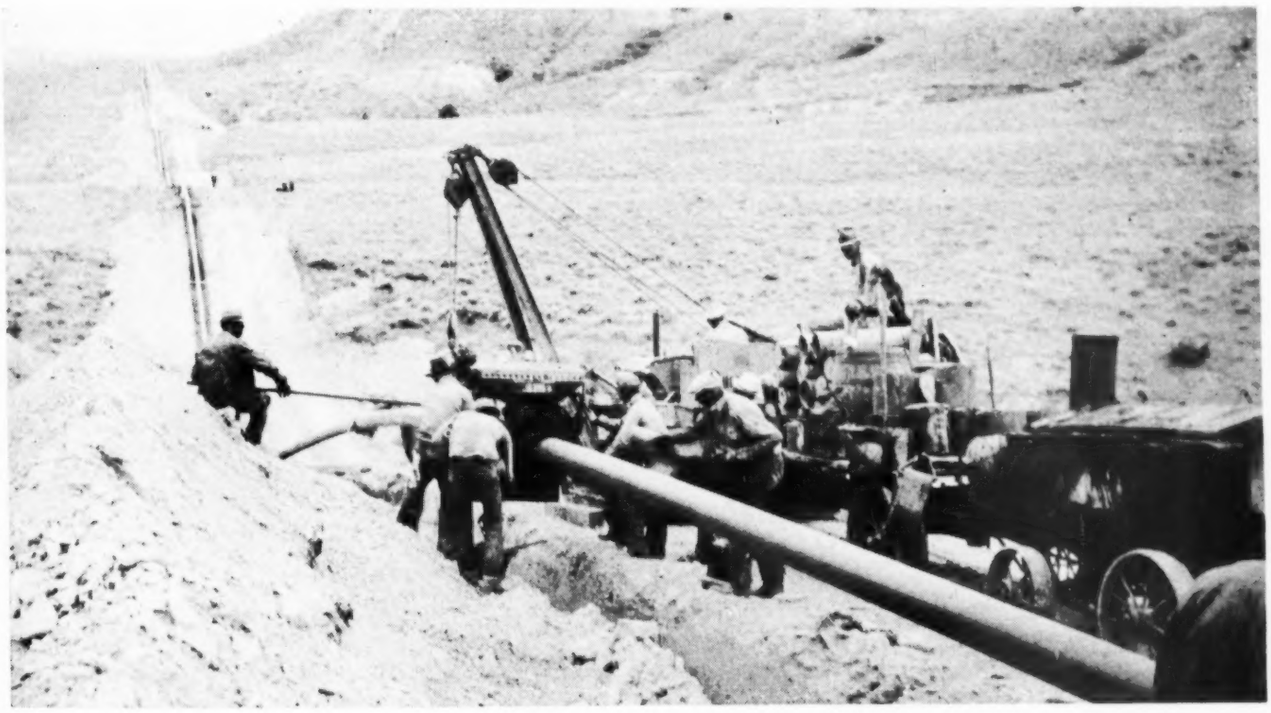
The country is rough and broken especially on the north end of the line to Laramie River, a distance of about 50 miles. South of Laramie River the

Making a road crossing

right-of-way is rough and broken for a total distance of about 20 miles, the remaining distance being relatively level.

Throughout the line a ditch 24 in.

A part of the line was laid through rolling country as shown here



Lowering-in

wide and 32 in. deep was dug by two regulation type ditching machines.

Although the entire line was electric welded some of it was by the "stove-pipe" method and some by the "firing line" method. Through the rough areas, which in all totaled about 96 miles, the "stove-pipe" method was employed. For the most part fast welding speeds were possible. On those sections where firing-line welding was employed about two and one-half miles were averaged per day.

Two river crossings were installed, across the Laramie and the North Platte. The North Platte River crossing is approximately 400 ft. in length and the Laramie River crossing about 200 feet. In making the former 10-in. pipe was used, resting on the river bottom without clamps. On the Laramie River crossing pipe line clamps were used.

The line is being tested in sections by air pressure. Gate valves are being installed every five miles.

Pipe coating and wrapping is being done by a new type machine that applies the coating hot and wraps the pipe in one operation as it travels along the pipe.

All pipe bends are made cold by gravitational means, i.e., lifting the pipe by tractor and winch above the ditch and utilizing its own weight to bend it to the desired angle.

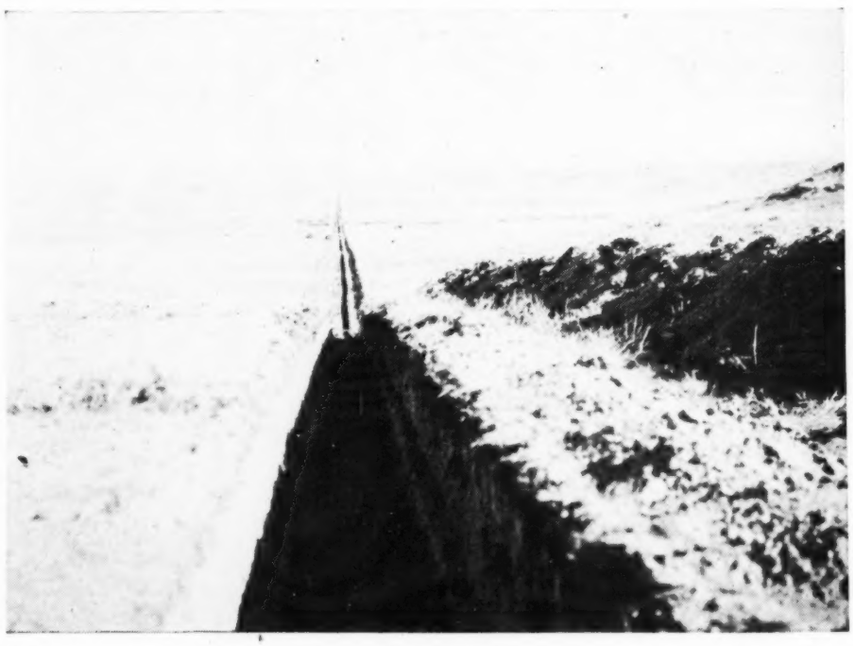
Two methods of lowering-in are being employed. In some instances slack loops are held up on skids and lowered-in during the cool of the morning. At other times slack loops are crowded into the ditch. Conventional backfillers are used to cover the pipe, but at times the rocky nature of the fill makes it necessary to sift it to prevent damage to pipe coating and wrapping.

Pipe Line Stations

Two pumping stations are being constructed, one at Lance Creek and one at Cheyenne. Equipment at the Lance Creek station consists of one 300-hp., 3-cylinder, angle-type, 2-cycle, gas engine connected to a 4¾-in. by 24-in. pump. The engine will be equipped with closed coil pipe line water coolers and air-starting units. Two 80,000 bbl. tanks and two 10,000 bbl. tanks having pontoon-type floating roofs and automatic tank gauges also will be provided. The station building will be of frame construction covered with corrugated iron. Floors will be of colored concrete. Nine four-room modern cottages will be constructed for employees.

At the Cheyenne pump station there will be one 360-hp., 5-cylinder, Diesel engine connected to a 4¾-in. by 24-in. pump. Here, also, closed coil coolers and air-starting equipment will be provided. There will be two 10,000 bbl. welded tanks having floating roofs and automatic tank gauges. Two modern four-room cottages are being built, and because the station is about 20 miles from the city of Cheyenne it will have its own electric generating plant, consisting of two 15-kw., 1800-r.p.m., 110-volt generating units.

Crude oil pumped through the new line will have for its destination the Continental Oil Company's and the Bay Petroleum Corporation's refineries at Denver, and the Lance Creek-Glenrock section will terminate at the Continental Oil Company's refinery at Glenrock. At Denver a terminal is being constructed from which deliveries will be made. Equipment at this section will consist of two 80,000-bbl. welded steel tanks having floating-type roofs and automatic tank gauges, as well as the necessary pumping equipment.



A ditch 24 in. wide and 32 in. deep was dug

Slide Rule Mechanics For Pipe Line Engineers

Convenient operations that simplify the use of the instrument

By FRANK E. HANGS

THERE are numerous convenient slide rule operations that greatly simplify a lot of the "guesstimating" the average pipe line engineer is required to do. Some of these, which have been gleaned from various sources and have been tried in the office and field, are here presented. A, B, C, and D refer to the lettered scales on the slide rule.

Plunger Pumps

Displacement varies as the square of the plunger diameter for a given pump (speed constant). Suppose we know the displacement of plungers of a given size.

I.

A	Under given displacement.
B	Read new displacement.
C	Set new diameter.
D	To given diameter.

II.

A	To given displacement.
B	Set desired displacement.
C	Read new diameter.
D	Over given diameter.

The displacement may be stated in any consistent units, gal. per min., bbl. per hr., or bbl. per day, and one will always be able to read the corresponding value.

Centrifugal Pumps

Discharge varies as the speed for a given pump.

Head varies as the square of the speed. Here again discharge may be stated in any consistent units and head may be stated in ft. or lb. per sq. inch.

III.

A	Under given head.
B	Read desired head.
C Set desired speed.	Read desired discharge.
D To given speed.	Over given discharge.

IV.

A	To given head.
B	Set desired head.
C Read desired speed.	Read desired discharge.
D Over given speed.	Over given discharge.

Note that once the speed ratio is set on the C and D scales a whole new characteristic curve can be drawn by transforming points on the original curve simply by leaving the rule fixed and moving the runner. It is very important to remember that for each speed change there are always changes in both head and displacement for any point on the original curve.

Also note that for centrifugal pumps driven through gears we can obtain the same results by using the ratio of engine or motor speeds instead of pump speeds.

Changing Impeller Diameters

Displacement varies directly as the impeller diameter for a given pump at constant speed.

Head varies as the square of the impeller diameter.

V.

A	Under given head.
B	Read required head.
C Set desired displacement.	Read required diameter.
D To given displacement.	Over given impeller diameter.

We might desire a certain head:

VI.

A	To given head.
B	Set desired head.
C Read new displacement.	Read required diameter.
D Over given displacement.	Over given impeller diameter.

It is well to remark that these diameter changes are usually of small magnitude. Generally it is advisable to call upon the pump manufacturer for his recommendations.

We might wish to build a characteristic curve for a pump at the same speed as another of different impeller diameter. (Same number of stages assumed.)

VII.

A	Under given head.
B	Read new head.
C Set new diameter.	Read new discharge.
D Over given diameter.	Over given discharge.

This impeller diameter ratio is very similar to the speed ratio in III. As before, there are changes in both discharge and head when a point on the given curve is transformed to the new curve.

The power required because of a speed change can be found as follows, on rules that have a cube or K scale.

Horsepower varies as the cube of the speed.

VIII.

C Set given speed.	Opposite new speed.
K To horsepower at given speed.	Read required horsepower.

Pressure Drop of Fluid in a Given System

If we know the pressure and flow under certain conditions we can quickly determine the effect of changes in either the pressure or flow. (Viscosity, gravity, etc., remaining the same.)

Pressure drop, total or unit, varies very nearly as the square of the quantity of fluid, gal. per min., bbl. per hr., or bbl. per day. This ratio is not mathematically rigid because of the friction factor; nevertheless, it is very useful.

IX.

A Under given pressure.	Under desired pressure.	Read desired pressure.
B Set given flow.	Read desired flow.	Over desired flow.

Cubic Contents of Pipe

X.

A Read barrels.	Vice versa also.
B Over length of line in feet.	
C Set 3.21 for all pipe.	(4.95 for gallons).
D To diameter in inches.	

One should always use a little common sense when using a slide rule. Remember the rule is only a mechanical device. Run through problems mentally. If the speed or plunger size of a pump is increased then the displacement must be increased also. One can thus avoid some common errors, and after a small amount of practice can become adept with his rule.

CLARK "ANGLES" IN K.M.A. FIELD Equipped to give Low and High Pressure Service

IN Continental Oil Company's new natural gasoline plants in the K. M. A. field at Wichita Falls, Texas, CLARK "Super-2-Angle" Compressors have been specially equipped for both low and high-pressure service.

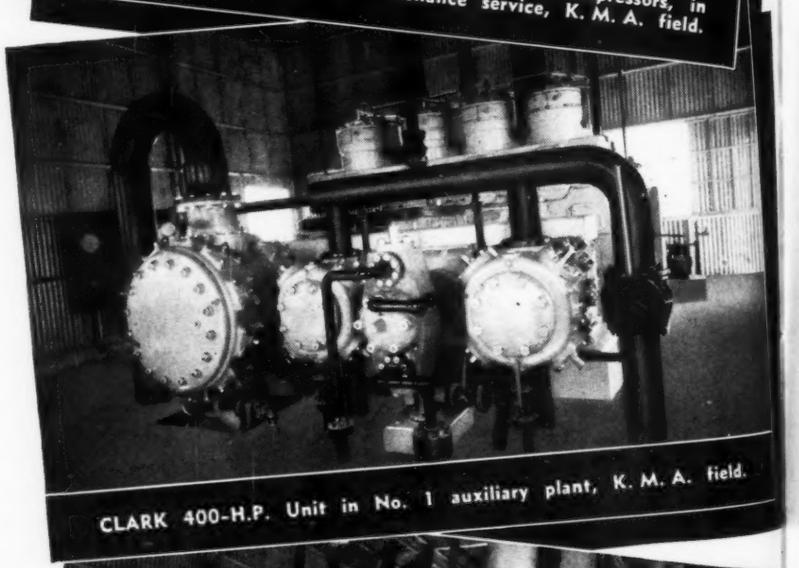
In low-pressure service, the compressors are being used for extracting gasoline from the wet gas. In high-pressure service, the compressors will be used, later on, for maintaining reservoir pressure in the field, by boosting the dry gas and returning it to the formation.

To serve this dual purpose, each CLARK unit has been designed for three-stage compression—with one cylinder on the low stage, two cylinders on the intermediate stage, and one cylinder on the high stage, for pressure maintenance and repressuring.

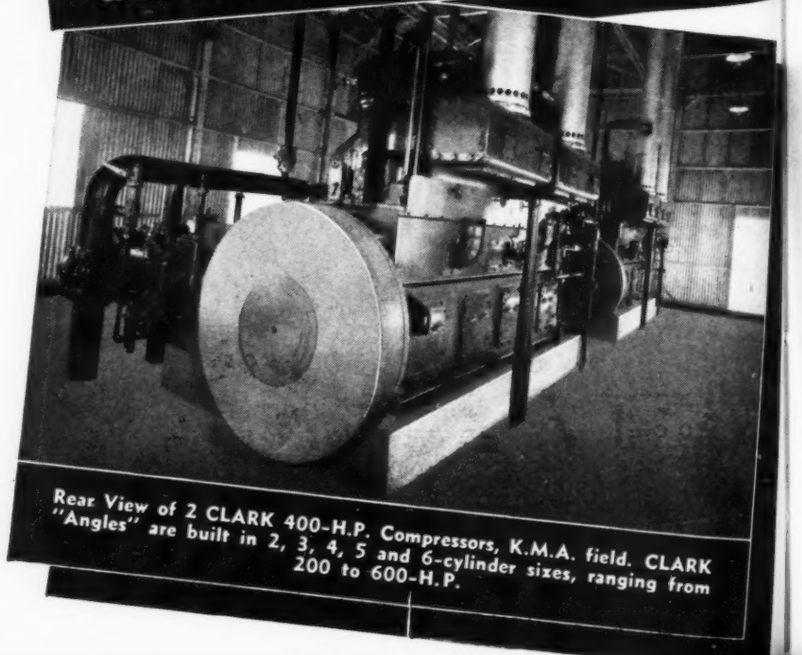
In the three-plant system at K. M. A., there are two CLARK 400-H.P. units in the main plant; one 400-H.P. unit in the No. 1 auxiliary plant; and two 400-H.P. units in the No. 2 auxiliary plant. Each compressor has a capacity of 2,000,000 cubic feet of gas per day.

CLARK "Angle" Compressors are being used in the Industry's most important gasoline plant and pressure maintenance projects, including the world's highest pressure gas-conservation plant at Tepetate, La. Write for descriptive bulletins and new catalog.

2 of the 5 CLARK 400-H.P. "Super-2-Angle" Compressors, in natural gasoline and pressure maintenance service, K. M. A. field.



CLARK 400-H.P. Unit in No. 1 auxiliary plant, K. M. A. field.

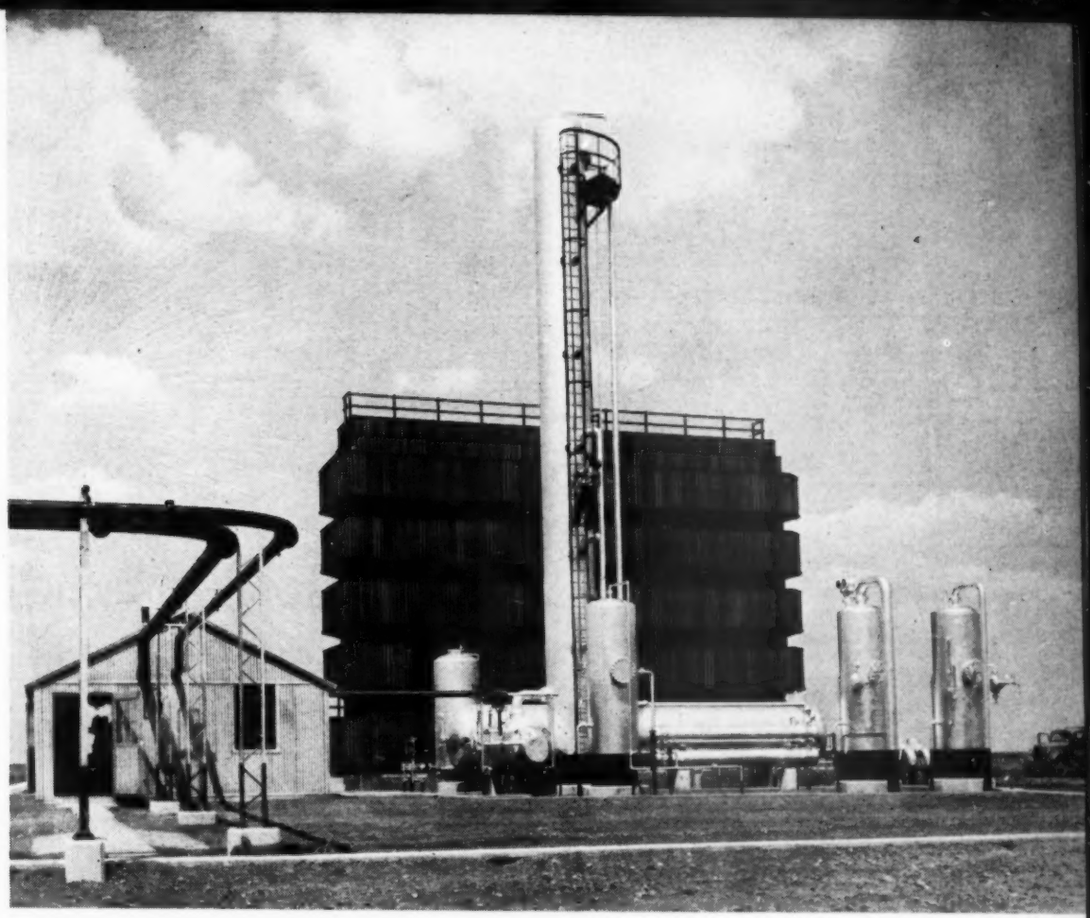


Rear View of 2 CLARK 400-H.P. Compressors, K.M.A. field. CLARK "Angles" are built in 2, 3, 4, 5 and 6-cylinder sizes, ranging from 200 to 600-H.P.

CLARK BROS. COMPANY, Olean, New York

Export Office: 30 Rockefeller Plaza, New York. Mid-Continent Sales Offices and Warehouses: Tulsa, Okla.; Dallas and Houston, Texas. West Coast Office: Smith-Booth-Usher, 2001 Santa Fe Ave., Los Angeles. Foreign Offices: 72 Turnmill St., E. C. 1, London, England; 4 Str. General Poetas, Bucharest, Roumania.

CLARK



View of main plant showing pump house, stabilizing tower, intake scrubber, cooling tower, high- and low-stage accumulators, and high-pressure make tank

Multiple Plant Processing of Gas in the K. M. A. Field

Economies in pipe and transmission costs made possible by arrangement of plants for compression of gas for gasoline manufacture and repressuring

By E. O. BENNETT[1] and R. A. CARTER[2]

THE Continental Oil Company is employing an unusual arrangement of several plants in the K.M.A. field, Wichita County, Texas, for the manufacture of natural gasoline and the return of residue gas to the producing formation. Three plants were recently erected at various points throughout the field. All manufacture raw gasoline but the entire production of the three is treated for removal of sulphur and stabilized at the main plant.

Such an arrangement makes possible the use of shorter gathering and return lines and, for the gathering lines, pipe of smaller diameter can be employed owing to the reduction in pressure drop.

The plants are connected to about 400 wells and have a total capacity of approximately 9,500,000 cu. ft. of casinghead gas per day.

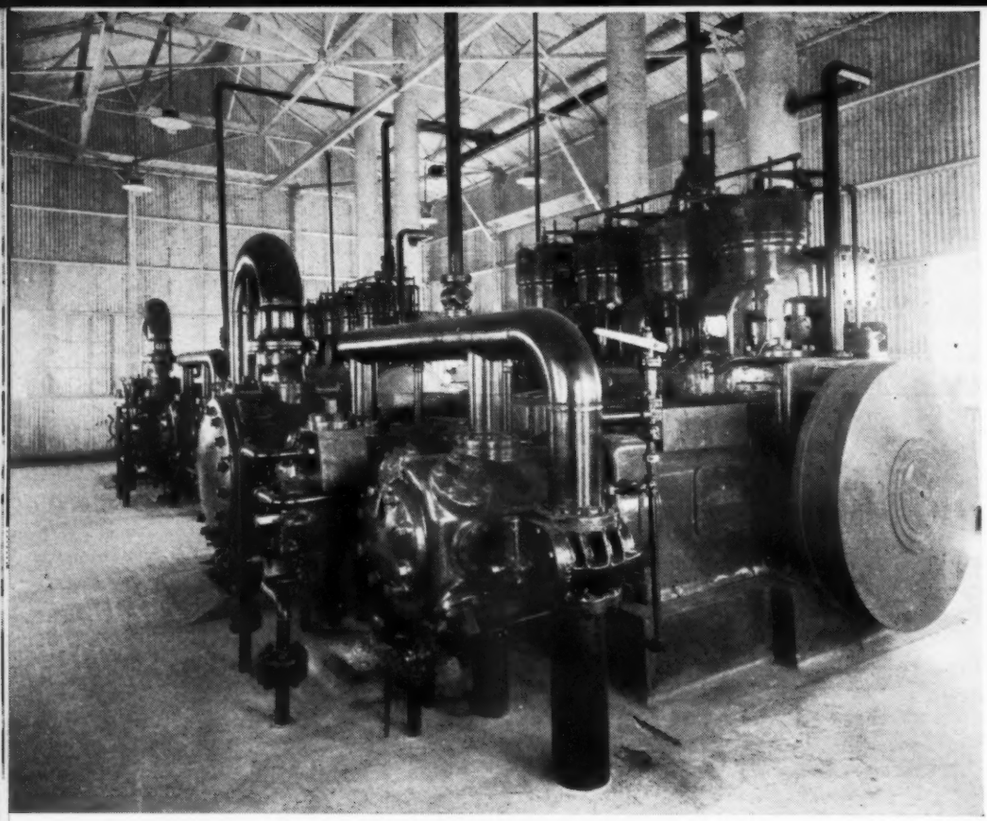
[1]Chief Petroleum Engineer, Production and Drilling Department, Continental Oil Company.
[2]Superintendent, Natural Gasoline Department, Continental Oil Company.

The gathering lines consist of about 100 miles of pipe ranging in size from 2-in. to 18-in. diameter.

Main Plant

Gas received at the main plant, situated on the J. and J. Waggoner lands north of Wichita River near the Rocky Point school, is passed through the 6-ft. diameter by 10-ft. intake scrubber to eliminate all liquids. This scrubber is equipped with a float-controlled mercoid switch for shutting-down the plant in event of high liquid level. The field gas is at a pressure of ten in. of vacuum and after being scrubbed is sent to the 29-in. low-stage cylinder of the compressor units and compressed to 30-lb. pressure. In the atmospheric-type cooling tower the gas is cooled to within five deg. of wet bulb temperature, being then sent to the low-stage accumulator where condensate is eliminated. The accumulator is equipped with two float controls and a mist extractor. One controls the pump that pumps condensate into the high-pressure make tank, the other being a mercoid float that shuts down the plant to avoid serious damage to equipment in event of pump failure or if for any other reason the height of the liquid level becomes excessive.

From the low-stage accumulator the gas goes to the suction of the 10½-in. high-stage compressor cylinders, of which there are two on each unit, and is compressed to 300 lb. gauge. It is again cooled in the tower to a temperature about five deg. above wet bulb, then passes to the high-stage accumulator, being virtually free of pentanes. The residue gas is utilized for fuel in the field and soon will be used for repressuring also. The gasoline condensate is boosted by its own pressure to the 6-ft. diameter by 36-ft. high-pressure make tank, which operates at a pressure of 175 pounds. The stabilizer charge pump moves the gasoline from the tank to the stabilizer, which has a capacity of 60,000 gal. per day, where it is finished to the desired grades, from



400-hp. angle-type compressor units at main plant

14- to 26-lb. Reid vapor pressure. At present an 18-lb. gasoline is being manufactured.

As the gas contains some sulphur it is necessary to treat the gasoline. The dry copper process is employed to sweeten the finished product. The gasoline is stored in five 10-ft. by 40-ft., 25,000-gal. tanks until it is pumped through a 3-in. line to the loading rack six miles north of the main plant.

Compressor Units

The main plant is equipped with two 400-hp. Clark angle-type compressor units having a speed of 300 r.p.m. and a capacity of 1,900,000 cu. ft. per day each. The gas is compressed in two stages from an intake pressure of ten in. of vacuum to a discharge pressure of 300 lb. gauge. Each unit has one 29-in. low-stage and two 10½-in. high-stage compressor cylinders. On special request the manufacturer designed a 2¾-in. high-pressure cylinder for repressuring work, which is attached to the scavenging cylinder of the units. This cylinder is designed to return the gas to the producing sand at a pressure of 2000 pounds. One such cylinder is attached to each engine and individually they can compress 225,000 cu. ft. of gas per day.

Standard equipment for all engines includes an air-starting cock, oil pump, oil filter, oil cooler, water funnels, lubricator (the equipment has full force-feed lubrication), overspeed stop, and oil safety device. A special instrument board is provided, having all the required instruments, such as tachometer, exhaust temperature thermocouple indicator, and oil temperature and pressure gauge.

The jacket-water cooling system is of the closed type. Turbine-driven twin pumps circulate water from the engines through three single-pass cooling sections in the base of the cooling tower. The coils are of the atmospheric type and each section is 614 sq. ft. in area.

Starting-air is provided by a 20-cu. ft. per min., gasoline-engine-driven compressor. Air is delivered to the engines at a pressure of 200 lb. from two 2-ft. by 8-ft. horizontal air bottles.

Steam Plant

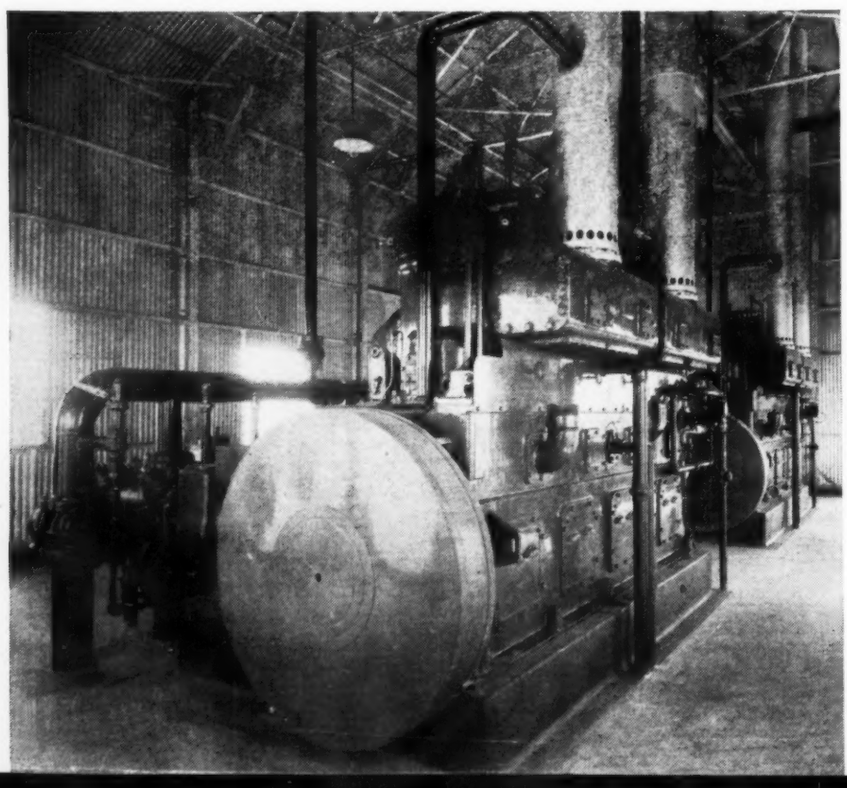
Two 125-hp. oilfield-type boilers equipped with a water regulator and low-pressure burners and operating at a pressure of 200 lb. are used in generating steam. The steam plant also has as equipment one raw water makeup pump and a boiler-feed makeup tank. A float control automatically maintains a constant level in the tank. The 1000-bbl. raw water tank is supplied from a large earthen reservoir that covers about 20 acres situated two miles north of the plant. This reservoir is filled by surface water. Before going to the boilers the feed-water is heated by exhaust steam to a temperature of about 200 deg. fahrenheit.

Cooling Towers

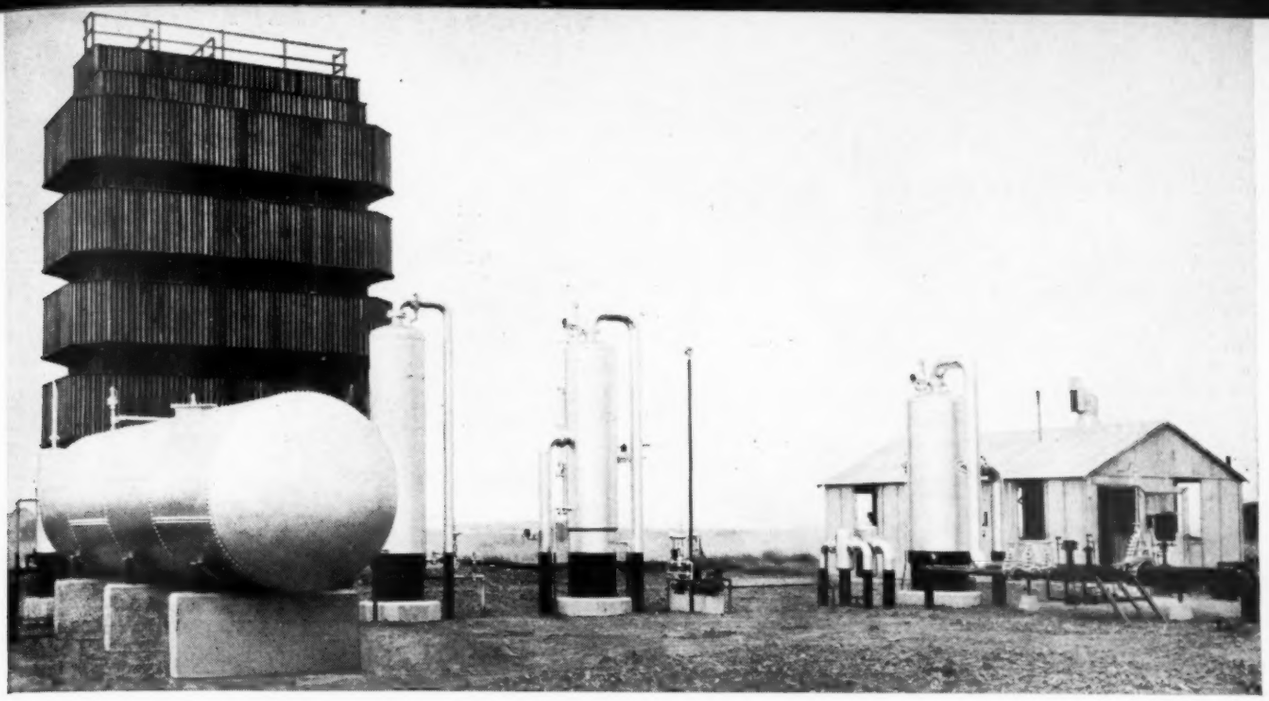
At the main plant is a 10-bay Fluor atmospheric-type cooling tower, 66 ft. 2 in. long by 23 ft. 7 in. wide by 45 ft. 11½ in. high. A turbine-driven pump circulates water over the tower and in the base are situated the cooling coils. Smaller towers are provided at the auxiliary plants. Cooling tower makeup water is obtained from a water well 30 ft. deep operated by gas-lift. This tower, as well as those at the auxiliary plants, has primary and winter auxiliary distribution systems.

Pump House

The pump house is of sectional-steel construction, measuring 20 ft. wide by 40 ft. long by 6 ft. eaves. In it are three 5½-in. by 2½-in. by 7-in. simplex pumps, one 10-in. by 7-in. by 18-in. pump, one 6-in. by 6-in. by 12-in., two 6-in. by 4-in. by 10-in., one 16-in. by 7-in. by 18-in., and one 6-in.



Interior of compressor house, No. 2 Auxiliary Plant



No. 1 Auxiliary plant. Left to right—cooling tower, raw gasoline storage tank, high- and low-stage accumulators, intake scrubber, and pump house

by 4-in. by 6-in. pumps. These pumps are used to circulate water over the cooling tower and to the engine jackets, to pump stabilizer charge and reflux, to boost the finished gasoline from storage to the loading rack, for general utility work, and as standbys.

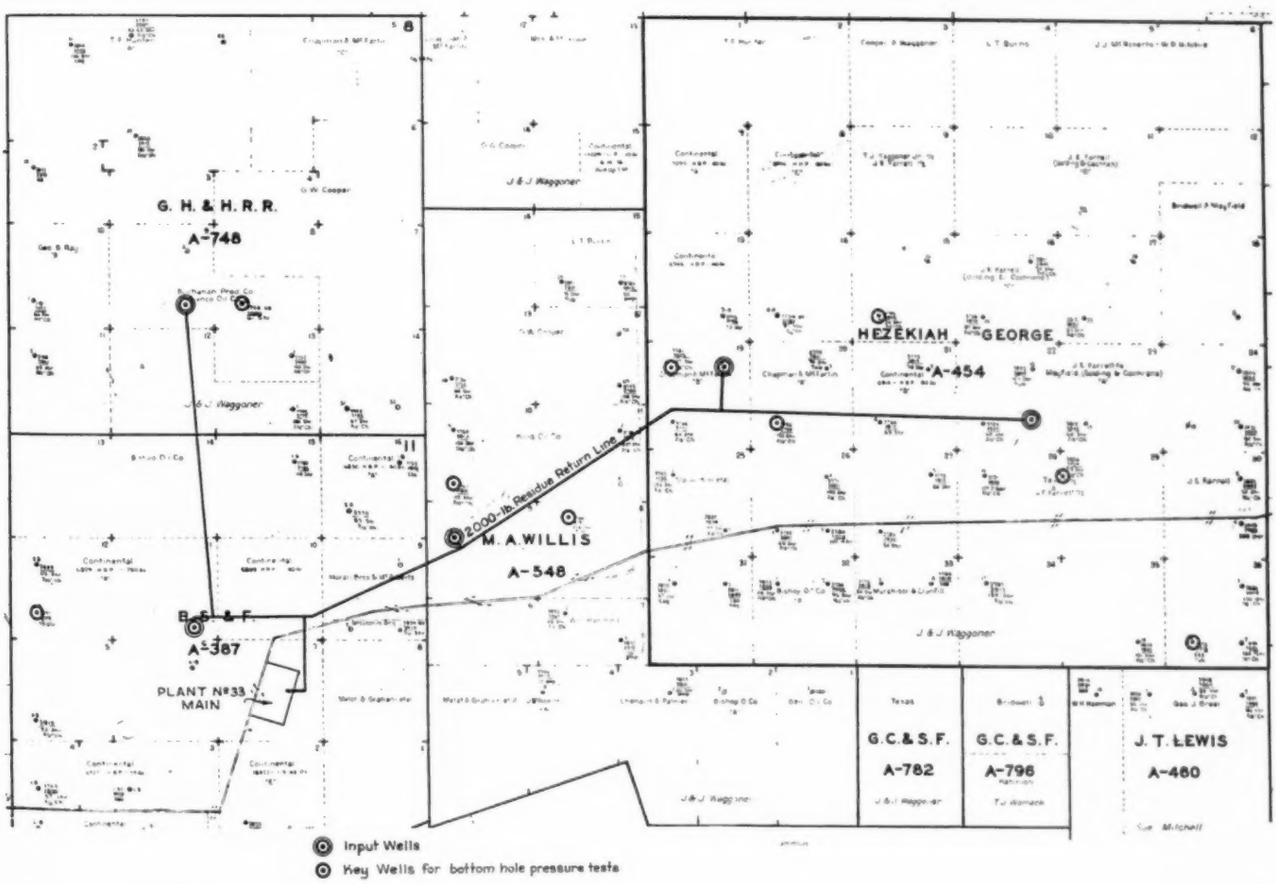
Generating Plant

Electricity for lighting the plant is generated by a 20-kva., 110-volt a-c. generator direct-driven by a V-8 industrial-type engine operating on gas. All interior light fixtures are vapor-proof and outside wiring is of parkway cable and is underground.

Cooling Sections

For interstage cooling there are two single-pass sections, each having 472 sq. ft. of surface, and two single-pass

Map showing location of gas distribution lines and wells for gas injection and for measurement of reservoir pressure



sections each of 614 sq. feet. The former are for gas-cooling following low-stage compression and the latter after the high-stage. Jacket water is cooled in three single-pass sections of 614 sq. ft. each, and the stabilizer reflux in three single-pass sections, each having 666 sq. ft. of surface. One 3-pass section having 200 sq. ft. of surface is employed to cool the gasoline after it has been stabilized. Cooling sections were manufactured by Joseph A. Coy, Inc.

Buildings

Most of the buildings are of sectional-steel construction. The compressor house is 30 ft. by 50 ft. by 17 ft. eave, the boiler house 30 ft. by 30 ft. by 12 ft. eave, the pump house 20 ft. by 40 ft. by 6 ft. eave, the fire house 6 ft. by 8 ft. by 8 ft. eave, and the shop 16 ft. by 24 ft. by 8 ft. eave. The office and laboratory are housed in a building having a wooden frame and corrugated-iron sheathing and roofing. It is a building 16 ft. by 24 ft. by 8 ft. eave.

The company camp consists of four cottages.

No. 1 Auxiliary Plant

The operation of the auxiliary plants is similar to that of the main plant, except there is no stabilizing, steam, or treating equipment. The gas is compressed in two stages and the raw gasoline sent to the main plant for finishing.

The No. 1 auxiliary plant, on the Ferguson land about a mile west of Kadane Corner, has one 400-hp. angle-type Clark engine connected to one 29-in. low-stage compression cylinder and two 10½-in. high-stage compression cylinders. The compressor house is a 30-ft. by 30-ft. by 17-ft. eave building of sectional-steel construction.

Two sets of twin water pumps, each set driven by a V-8 engine operating on gas, are employed to circulate water over the cooling tower and through the engine jackets. The cooling tower is a 4-bay model and is 30 ft. 2 in. by 23 ft. 7 in. by 45 ft. 11½ inches. A raw gasoline storage tank is provided at this plant merely as a precautionary measure, as, unless operating trouble makes the storing of the manufactured product necessary, it is sent directly to the main plant for stabilization.

Electricity for lighting is generated by a 15-kva., 110-volt generator driven by a gas engine. Scrubbers include a 4-ft. diameter by 10-ft. vertical inlet scrubber equipped with mist extractor, a 3-ft. diameter by 10-ft. low-stage scrubber, and a 3-ft. diameter by 12-ft. high-stage scrubber, the latter also being equipped with a mist extractor.

Cooling sections consist of one 472-sq. ft. section for interstage cooling, one 614-sq. ft. section for high-stage cooling, and two sections, each having 472 sq. ft., for cooling jacket water.

No. 2 Auxiliary Plant

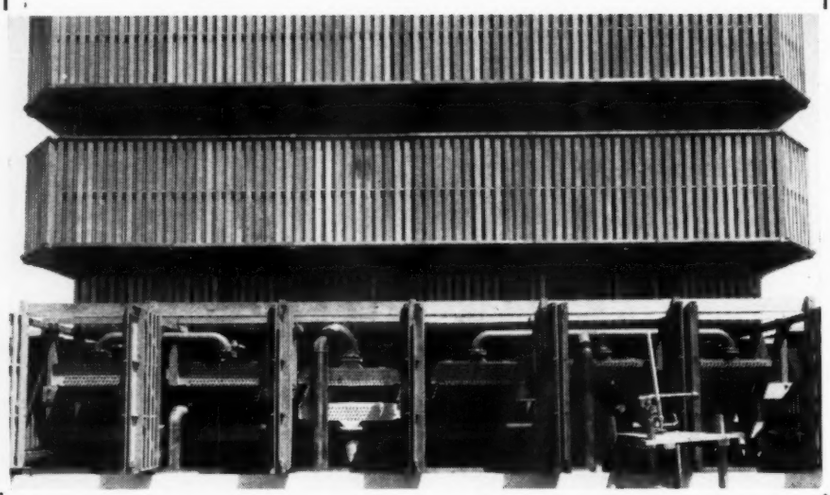
The No. 2 auxiliary plant is on the Hooks land about one mile north of the Valley View school. Two 400-hp. angle-type compressor units were installed at this plant. The units are duplicates of the ones at the main plant and the No. 1 auxiliary plant. The compressor house is of sectional-steel construction and is 30 ft. by 50 ft. by 17 ft. eave.

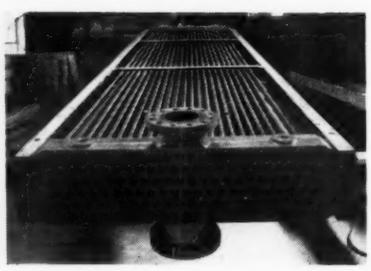
In the 16-ft. by 24-ft. by 8-ft. pump house are housed three 85-hp. gas engines each driving single reciprocating water pumps. One pump is for boosting water over the cooling tower, one for circulating engine-jacket water, and the third is used as a standby.

The cooling tower is a 6-bay unit measuring 42 ft. 2 in. by 23 ft. 7 in. by 53 ft. 11½ inches.

The inlet scrubber is a 6-ft. diameter by 10-ft. vertical unit, and the interstage scrubber a 4-ft. by 10-ft. unit. Two cooling sections of 472 sq. ft. each are provided for interstage cooling, two sections of 614 sq. ft. each for high-stage cooling, and three sec-

Battery of COYNCO Straight Tube Sections





In the New CONTINENTAL KMA Plaut

There are many reasons why Coynco Straight Tube Sections are being installed in ever increasing numbers in important plants:

1. Low initial cost.
2. Simple, fool-proof design
3. Quick, easy repairs without breaking pipe connections.
4. Tube arrangement for easy cleaning.
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tions of 614 sq. ft. each for jacket-water cooling.

Gas Analysis

As mentioned, the gas contains sulphur and the gasoline manufactured from it must be treated. The gasoline content ranges from 2.5 to 6.16 gal. per M cu. ft. of gas, according to the well and area of the field from which it is produced, but the following is an analysis of what is considered a representative sample of gas:

Constituent	*Mol Percent*
Methane	41.18
Ethane	13.82
Propane	22.10
Butanes	14.33
Pentanes plus	7.51
Air	.96
Acid gases	.10
	100.00

Calculated specific gravity, 1.216

Calculated B.t.u, 1977

Pressure Maintenance

A high-pressure residue system is being installed, which will return gas to the leases connected to the plant at pressures exceeding those in the producing zone in order to maintain, so far as possible, the original pressure.

The first unit for pressure maintenance in the K.M.A. field connected to Continental's plants will be installed on the J. & J. Waggoner Lands comprising the G. H. & H. R. R., B. S. & F., M. A. Willis, and Hezekiah George surveys. This block contains approximately 3500 acres and has at present 70 producing wells.

As shown on the accompanying map five input wells will be used to return gas to this area.

The wells are about 3760 ft. deep and are completed in the K.M.A. zone, some in lime and some in sand. No difficulty is anticipated in conducting pressure-maintenance operations in the lime, although it has not been generally practiced.

This is the first major project installed by a single company for the purpose of offering pressure-maintenance service to a large number of producers throughout a major oil field.

Three large additional areas will soon be supplied with high-pressure residue gas for return to the producing zone and it is anticipated that other operators in the K.M.A. field will also avail themselves of this service and that most of the K.M.A. pool will be operated under pressure maintenance, making the field the first and largest in the industry to be so operated. Such production methods are known to be conducive to the greatest possible ultimate recovery.

The compressed gas will be delivered to leases on a compression cost basis, the cost being determined by the pressure required for injection.

Continental Oil Company now has 2000 hp. in compressors installed. The machinery is new and of the latest and most efficient design, equipped with all known devices for continuous operation and protection against failure. The machinery is capable of returning gas to the high-pressure residue system at pressures to 2000 lb. per sq. inch. This pressure will be sufficient to return gas to the formation against the highest pressure in any part of the field.

Meters will be set at each input well between the well and the control valve so that the static pressure pen on the meter recorder will at all times indicate the bottom-hole pressure conditions.

The Railroad Commission of Texas is very much interested in the conservation angle of the K.M.A. pressure-maintenance project, and its engineers have offered many helpful suggestions concerning the installation.

Certain wells, as shown on the accompanying map, are designated for pressure test wells and the formation pressure in these wells will be measured at least every 30 days so the pressure gradient over the entire field may be watched closely and controlled.

Most of the operators in the field are interested in pressure maintenance because of the worthwhile results of several recent installations. The general application of pressure maintenance throughout the entire pool will prove the advisability and economy of saving gas energy in a large producing field and will be reflected in greater returns on the capital invested.

It is anticipated that programs similar to the one now under way in the K.M.A. field will eventually be adopted by coöperative agreements in most new fields to the direct gain of all participants.

The Cost of Belt Slip . . . By W. F. SCHAPHORST

BELT slip is much more important and much costlier than is generally supposed by most oil-plant executives. It can generally be accurately determined by proceeding as follows:

When you want to figure the cost of belt slip you must first determine the "percentage" of slip, which is a simple matter when conditions in the drive are such that the driven pulley can be operated for a time "without load."

It is obvious that when no power is transmitted by a belt there is no slip. The driven pulley, then, will rotate as many times per minute as it is possible for it to rotate.

When the belt is transmitting full load, however, there is bound to be a resultant reduction in revolutions per minute. The driven pulley will not rotate as rapidly as when "unloaded," the speed of the driving pulley always being the same. The difference in r.p.m. divided by the r.p.m. when "unloaded" multiplied by 100 gives the "percentage" of slip.

For example, let us say that a given driven pulley runs 340 r.p.m. in an unloaded state. When the belt carries full load, the r.p.m. of the driving pulley being unchanged, the driven pulley makes only 320 revolutions per minute. What is the percentage of slip?

Applying the above rule we get:

$340 - 320 = 20$

$20 \div 340 = 0.059$

$0.059 \times 100 = 5.9$ percent slip.

Now, applying these figures to actual conditions, if the drive is a main belt drive it means that you are wasting 5.9 percent of your coal or oil bill, or electric power bill, because of belt slip alone. Thus, if you spend $10,000 per year for fuel or power you are losing:

$\$10{,}000 \times 5.9$ percent $= \$590.00$ per year due entirely to belt slip of the main drive.

This $590.00 per year is considerable, but how about the other belts? They may be slipping just as much, which could easily mean that your total loss because of belt slip is 10 percent, or $(\$10{,}000 \times 0.10) = \$1000$ per year.

There are several good methods to reduce slip to a minimum. A few cents invested in a first class belt treatment, making the belt pliable and increasing its friction coefficient, often will do the trick. Sometimes it is advisable to replace the belt with one that is modern and of high quality. Or, install an up-to-date pivoted base, or a suitable wrapper pulley. Hundreds of dollars per year can usually be saved in this way in nearly any plant. This applies to all kinds of belts, V-belts as well as flat.

Continuous DEHYDRATION

No Settling Period Required

One of the principal advantages of Petreco Electromatic Dehydration is its adaptability to any production system in such a manner that separation of the water from the oil is continuous as the crude passes through the dehydrator, involving no extra tankage or costly settling period before the cleaned oil is delivered to the pipe line company

As shown by the flow chart above, wet oil enters at the bottom of the dehydrator, the cleaned oil being discharged continuously at the top while the water is withdrawn from the bottom This continuous dehydration is of particular importance when large volumes of emulsified oil are treated.

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Today, in all parts of the world, the average operator drilling the average well has for his use the same type instruments that have helped to establish *fourteen consecutive deep well records!*

Martin-Decker Products are in use today on a majority of the world's oil wells. Operations are being put on a more highly scientific basis than ever before, largely due to the use of these products. Crooked holes are becoming the exception rather than the rule—drill pipe twist-offs, buckled rigs and mechanical difficulties are constantly decreasing. In general, Martin-Decker Products have gone a long way toward reducing operating costs and providing for safe, dependable and scientific well control throughout the world.

Martin-Decker will continue to pioneer new methods and instruments for the scientific development of tomorrow's oil industry.

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Oilfields of India, Burma, and the East Indies . . . . Geographical Distribution

Study of paleogeography necessary to understanding of petroleum accumulation

By JOHN F. DODGE

Professor of Petroleum Engineering, University of Southern California,

in collaboration with

WALLACE A. SAWDON

FOREWORD

MUCH of the information regarding the oil fields of Burma and the East Indies contained in the following articles was obtained by the writer during a trip in the fall of 1937 and early part of 1938. Some time was spent in London with Burmah Oil Company engineers and in The Hague with geologists and engineers of B.P.M. (Shell) before departing for "Down under" in October. The oily side of the trip began at Calcutta with a series of conferences with Burmah Oil Company geologists and engineers and with officials of the Geological Survey of India. The writer has reason in particular to remember with thanks Mr. Percy Evans, for many years senior geologist in Assam for the Burmah Oil Company and recently elevated to chief geologist for that company, and Dr. Heron and Dr. Wadia, respectively director and senior geologist of the Geological Survey of India.

From Calcutta we proceeded to Rangoon and up the Irrawaddy to Yenangyaung where we were the guests of the Burmah Oil Company. We returned to Rangoon and proceeded by steamer to Singapore via Penang, Port Swettenham, and Malacca. From Singapore we flew to Medan where we were the guests of B.P.M., being shown around the fields by Mr. P. M. DeBoer, the administrator, and a number of his engineers, in particular Mr. H. A. Van den Dungen, superintendent of the Rantau field. At Palembang our time was divided between B.P.M. and Koloniale, both royal hosts. Among the engineers of the latter company Messrs. Farley and Jack Berlin will be remembered by many of their American friends as former Standard Oil men at home.

From Palembang we flew to Batavia, hired a car and native driver, and toured Java to the tune of 1200 miles and many guilders. In Batavia we visited Carl Newcomb, manager in the N.E.I. for the Standard Oil Company of California (Md. Pac.) and at Tjepoe were again guests of B.P.M. where we have reason to remember most cordially Mr. Kunzli, the administrator, and Mr. Schot, the superintendent of Kawengan field.

JOHN F. DODGE

ALTHOUGH modern drilling methods were not developed until after the completion of the Drake well in 1859, the production of oil has been an established industry in Burma for several centuries. The early wells were primitive, hand-dug shafts and even today a part of India's production is obtained from hand-dug wells. Recently the average total production from producing areas of Burma and India has been somewhat more than 25,000 bbl. per day, but for two decades it remained virtually constant at slightly more than 20,000 bbl. per day. Of particular interest has been the extension of the existing producing fields in Burma during the last few years.

The petroleum resources of India are confined to the sites of three ancient gulfs, which are described by Eric J. Bradshaw[1] as:

"1. The Burmese gulf, covering what is now the basin of the lower Irrawaddy and its main tributary, the Chindwin, and opening southward into the Bay of Bengal.

"2. The Assam gulf, occupying the middle portion of the present Brahmaputra and debouching into the Bay of Bengal through the modern Meghna basin; and

"3. The Punjab-Baluchistan gulf, extending along the base of the Himalaya northwestward from a point opposite Naini Tal and curving around through the Potwar plateau south-southwestward through what are now the Baluchistan hill ranges to the Arabian Sea.

"In all three areas the oil is associated

[1] "Petroleum in the Indian Empire" by Eric J. Bradshaw. Transactions Petroleum Division A.I.M.E., 1931.

with Tertiary strata, and has had probably similar conditions of origin in all cases. In Burma it is known to occur in beds of Nummulitic age, but by far the greatest number of seepages and all the fields of importance are in the next highest geological series, to which there is every reason to suppose the oil is indigenous. In Assam oil is found in a similar series. In the Punjab, on the other hand, it is the Nummulitic which is the predominant oil-yielding series, and although the only supplies which have so far proved of economic importance are found in the series above, there is good reason to suppose that the oil has migrated up from the Nummulitic below. Whether in Burma, Assam, or northwest India, the occurrences of petroleum are always associated with an anticlinal structure."

Burma

Burma, which was a province of the Indian Empire until April 1, 1937, has been formally separated and is now an independent unit of the British Commonwealth. Its present production is nearly four times that of the two producing provinces of India, Punjab and Assam, but the prospects for increased production from Punjab are excellent at the present time.

All the Burma crudes are mixed-base oils having large paraffin content but containing only a small amount of asphaltum. None of the production, except for a negligible amount that was once produced at Sabe, requires dehydration and the sulphur content is very small. The crude needs only light refinery treatment and virtually all the fractions are marketable.

The present productive areas of Burma and Assam are shown on the accompanying sketch but most of the production from Burma comes from the Yenangyaung field and the Singu-Lanywa-Yenangyat area. The other producing areas of Burma are the Indaw or Upper Chindwin field, the Minbu fields, and the Thayetmyo fields. Gas is still being taken from the Pyaye field well but the I.B.P., which controls the field, has started a deep test for oil.

India

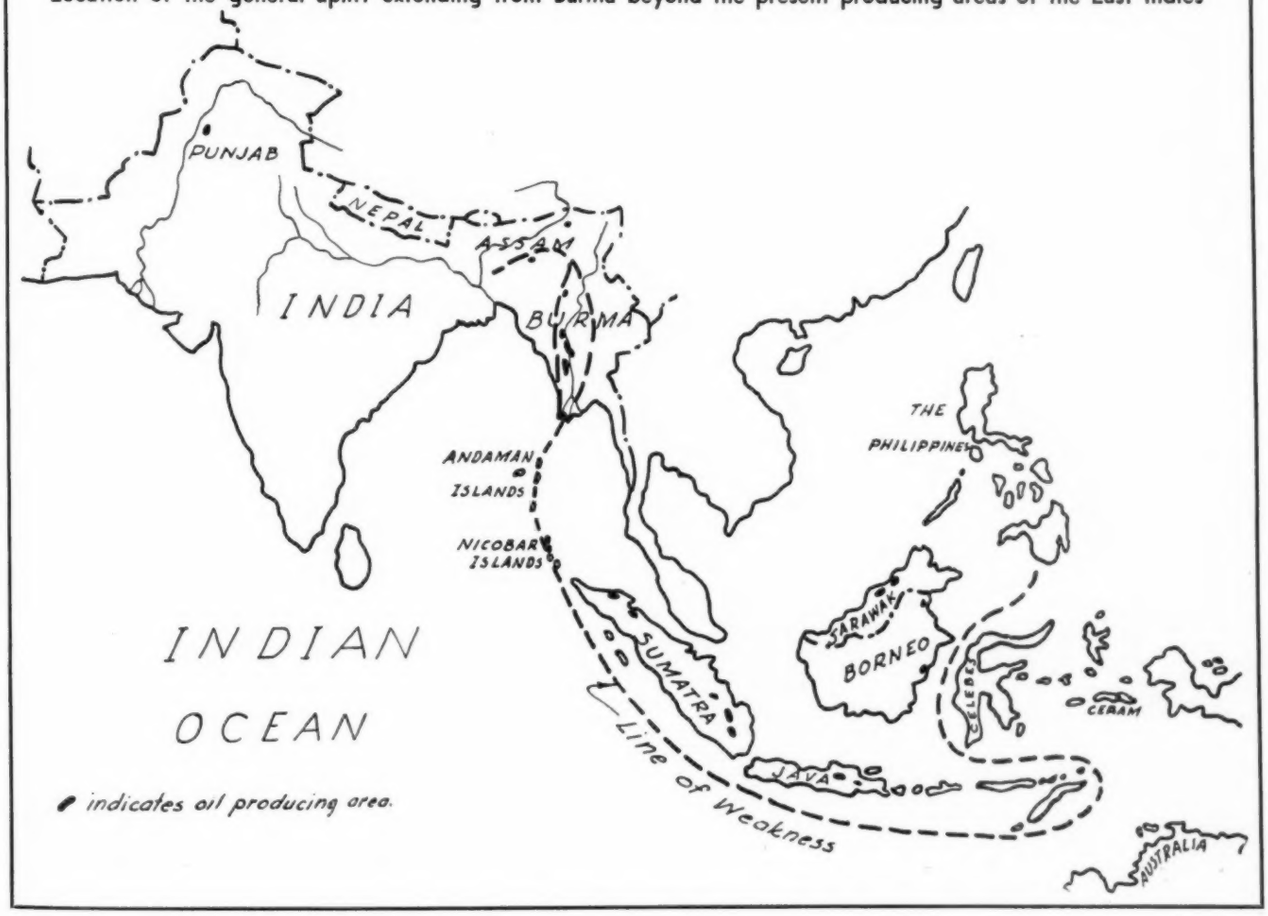
Virtually all production in Assam is obtained from the Digboi field situated in the Lakimpur district. A small field was drilled at Badarpur but it was disappointing. A great deal of exploratory work has been done in other areas without favorable results. Considerable geological work is being done and the Burmah Oil Company has a seismograph staff engaged continuously in some areas.

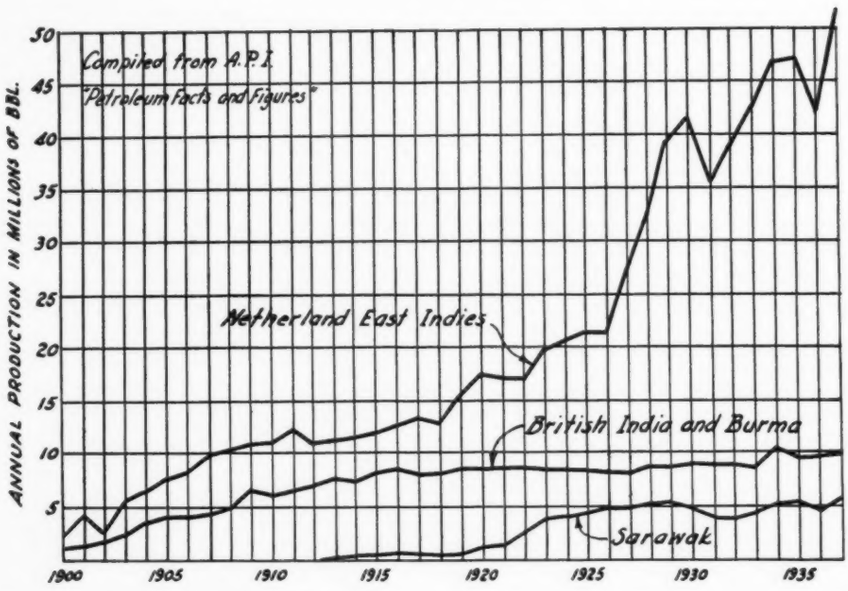
In Punjab production comes from the Attock fields at Khaur and Dhulian. High pressures have made completion rather difficult at Khaur although depths are not great. Most of the oil is obtained from the 3800-ft. sand. A test well on the open dome of Dhulian a few miles southwest of Khaur resulted in a discovery in limestone at a depth of 7800 feet. The first well produced more than 600 bbl. per day and three wells are producing all the oil the Attock Oil Company can handle at present.

The East Indies

Although the first production from these islands is recorded for the year 1893, oil seepages were known to exist in Sumatra, Java, and Borneo for a

Location of the general uplift extending from Burma beyond the present producing areas of the East Indies





Annual production from Burma, India, and the East Indies. Note the steady production from Burma and India for almost three decades

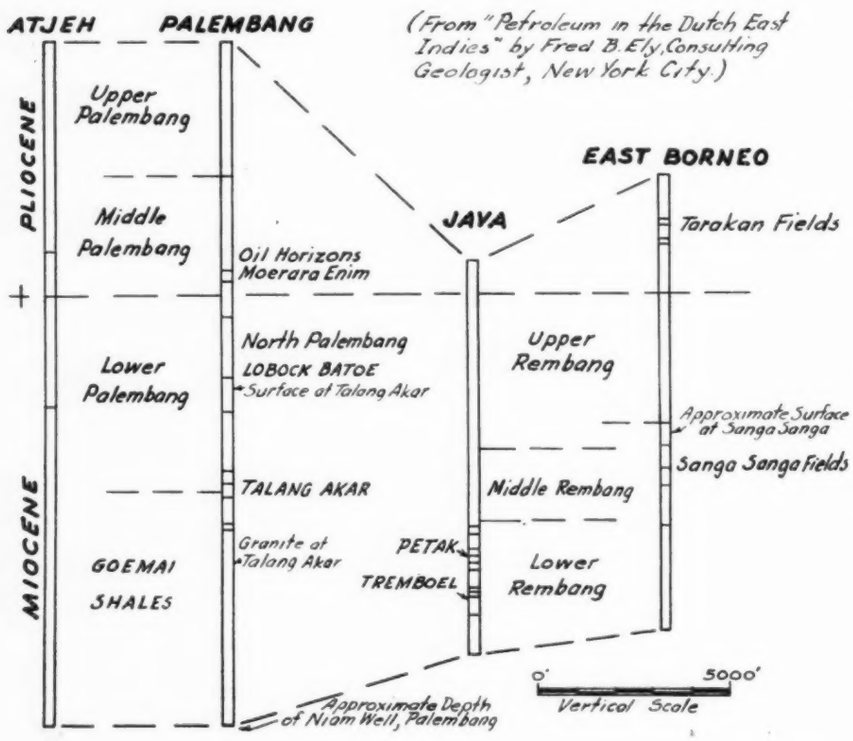
number of years previously. The present productive areas are northern and southern Sumatra, eastern Java, Sarawak, Brunei, Tarakan, and the southeastern coast of Borneo. A small amount is also taken from Ceram.

In southern Sumatra most of the oil is produced from the fields around Palembang. According to Fred B. Ely[2] there are 45 anticlines in this area, 27 of which have been productive or are producing oil. In northern Sumatra there are four main producing structures, which are situated near the shore.

The producing fields of Java are within an area 75 miles long by 25 miles wide.[2] There are 37 anticlines of which 25 have been productive.

In the Sanga Sanga district lying in the southeastern part of Borneo the pools are situated along a narrow folded ridge. This district yields most of the oil produced in Borneo. The Tarakan district in the northeastern part of Netherland Borneo includes the Tarakan field, which is situated on the island of that name.

[2] "Petroleum in the Dutch East Indies," by Fred B. Ely, Transactions Petroleum Division A.I.M.E., 1931.



Generalized cross-section, Netherland East Indies

The Miri district, along the northwestern side of the island of Borneo, is the principal productive area in Sarawak. Oil is obtained from sand lenses in the lower Miocene.

Northeast of Miri in the Sultanate of Brunei lies the active Seria field. This structure extends into the ocean.

Prospects on Other Islands and Australia

Core drilling and shallow hole operations have been in progress for some time in New Guinea (Papua) but it is now reported that three rotary outfits will be operating within a year. Two Diesel rigs and one steam rig and crews to operate them are being assembled.

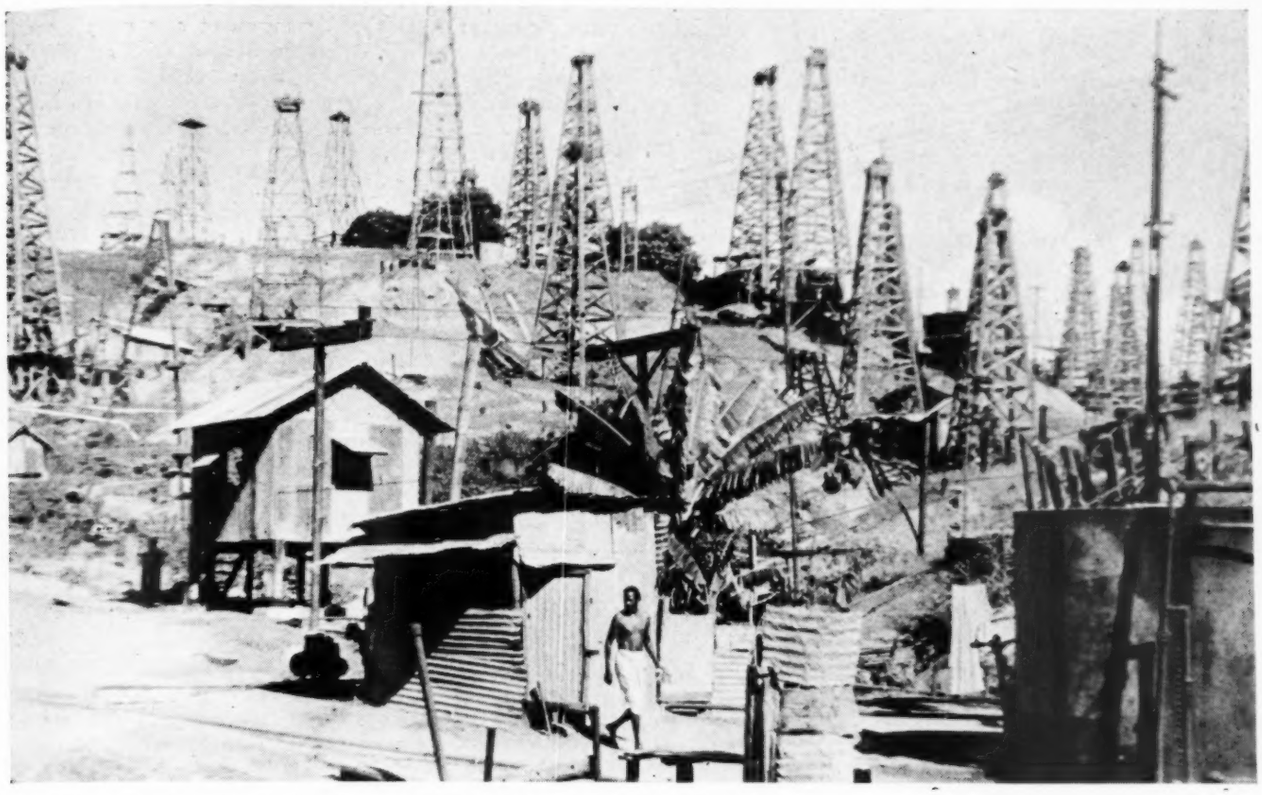
The holdings here are those of N. V. De Nederlandsche Nieuw Guinea Petroleum Maatschappij but the operations will be managed by B.P.M. Some of the staff has been borrowed from N.K.P.M. and N.P.P.M. and it is believed that these members are part of the geological staff. The facts that the deep tests will be drilled and that American drillers will be employed indicate that the area explored has proved promising.

Interest in the operations is divided as follows: 40 percent Shell, 40 percent Standard of New Jersey, and 20 percent Standard of California. The headquarters probably will be at Babo.

It is reported that the New Zealand Petroleum Company, a Standard-Vacuum organization, is moving a rig and crew to Gisborne, New Zealand.

Wildcatting continues in Australia but no commercial production has been reported. A number of cadet drillers, most of whom are Australians, are being taught the oil business in the Miri fields of Sarawak. It is understood, however, that they are being prepared for service in Papua.

There has been no production from the island of Celebes lying east of Borneo but oil seepages and asphaltic deposits have been found along both the east and west coasts.



Many of the wells in the Yenangyaung field, Burma, have been drilled on tracts only 60 ft. in circumference. Here is shown a part of the area that is probably the most closely drilled in the world

Intensive Drilling of Burma Fields Involves Unusual Problems

Development of bed of Irrawaddy River complicated by necessity of maintaining navigability

By JOHN F. DODGE and WALLACE A. SAWDON

THE principal oil fields of Burma are situated on Irrawaddy River about 300 miles north of Rangoon and less than 100 miles south and west of Mandalay, and extend along the river for a distance of forty or fifty miles southward from Yenangyat. Production is obtained from Middle Tertiary strata, the geologic column being as follows:

Irrawaddy Series		Pliocene	Surface
Pegu Series	Upper	Miocene	Oil zones
	Lower	Oligocene	
Shales and sands		Eocene	Non-productive

The average production during 1937 was approximately 22,000 bbl. per day. This oil is produced by three large companies and a host of smaller operators of which latter only one, the Nath Singh Oil Company, has an appreciable production. The Burmah Oil Company produces about 80 percent of the oil, or about 16,500 bbl., whereas the British Burmah Petroleum Company and Indo-Burma Petroleum Company together produce less than 5000 barrels.

With the exception of a small quantity processed in a few local tea-pot stills, all the oil is refined at Rangoon, where each of the major companies has a refinery. The fields of the Burmah Oil Company are connected by pipe lines, a 4-in. line running from Yenangyat to Singu and an 8-in. line from there to Yenangyaung. All the oil is transported to Rangoon through a 10-in. line approximately 275 miles long. The other operating companies convey their oil to the refineries in flat-bottom barges, which are lashed to steamers for transport down the Irrawaddy. Gravity of the oil is high, the average exceeding 45 deg. A.P.I. Gasoline content is large and the oil contains a considerable amount of high-melting-point wax, but almost no lubricants. Most of the oil produced by the Burmese operators is refined at Yenangyaung and is sold to bus drivers at the many settlements along the river. No fuel oil is produced as other products are too valuable.

Kerosene is produced in two grades. The higher priced grade is a treated product but the cheaper, which is blended with gas oil and light distillates, is used for illumination throughout the country. Paraffin wax is an important product and in processing is sweated and treated. This wax is the most important petroleum export. What lubricating oils are made are lightly treated with acids.

An interesting point in connection

with the refining of Burma crude is the considerable amount of high-melting-point waxes that can be obtained from it. A substantial quantity of wax having a melting point above 150 deg. fahr. is now produced and much more could be manufactured if a ready market for the product existed.

Both compression and absorption plants are used for extraction of gasoline from wet gas in the fields. The natural gasoline thus produced requires no treatment.

YENANGYAUNG FIELD

The headquarters of the Burmah Oil Company are at Khodaung, near Irrawaddy River in the midst of the Yenangyaung operations. Here are situated the main offices, warehouse, shops, and yards. The Yenangyaung field itself consists of a number of areas, which are locally given the names of Khangone, Twingone, Beme Chaung, and Minlindaung. Khangone is at the north end, Minlindaung at the south end, and Khodaung situated near the middle. This series of productive areas extends approximately seven miles in length from north to south and about three-fourths of a mile in width.

In this field the Irrawaddy Series is believed to overlie the Pegu unconformably; in fact, an overlap can be seen on the Yenangyaung anticline where Yenangyaung Creek has cut through the structure near Khodaung. The productive portions of the Pegu are at least 2000 ft. thick and probably considerably more, but the thickness is difficult to estimate because of the difficulties in correlating strata. Sands, sandy shales, and shales alternate but at Yenangyaung an arbitrary division is made:

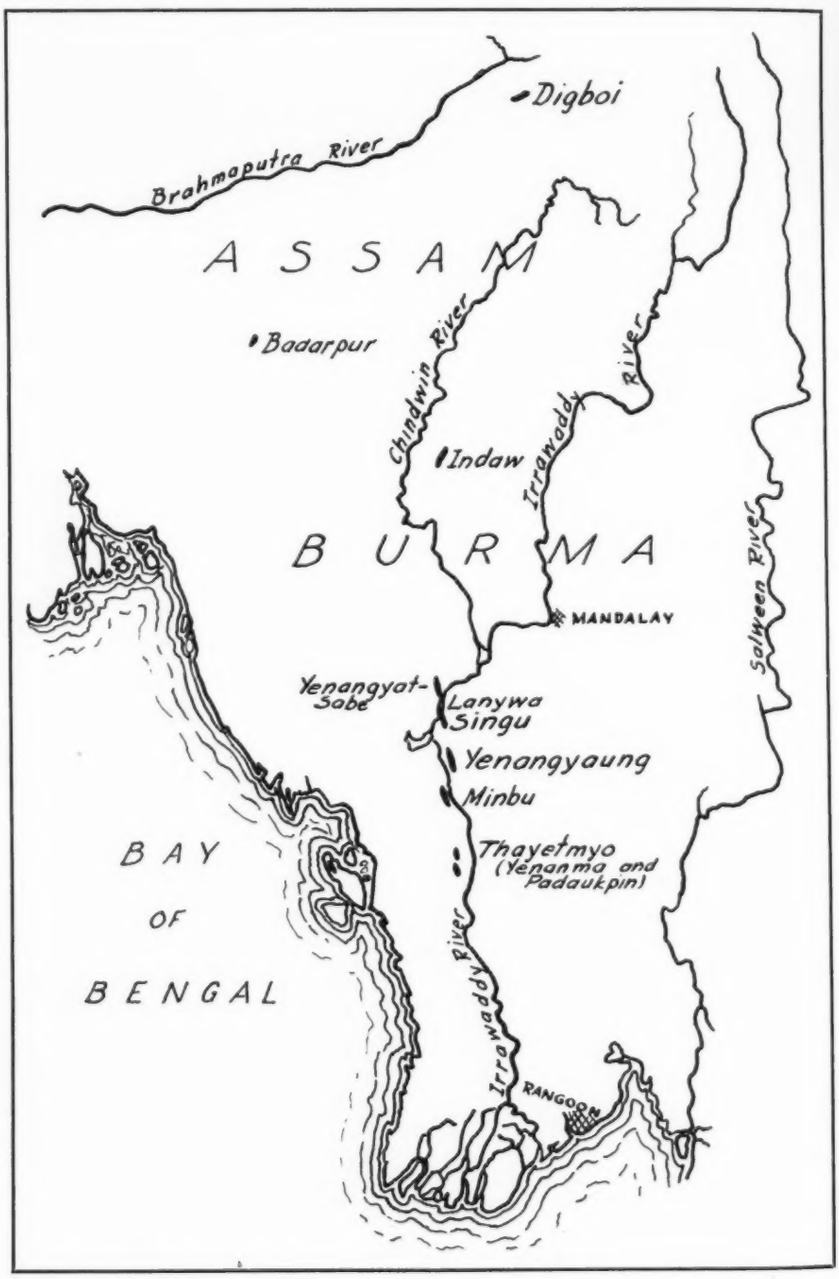
(a) Shallow sands..... 0 to 1000 ft.
(b) Intermediate sands .....1000 to 2000 ft.
(c) Deep sands .....Below 2000 ft. (stratigraphic depth)

The principal production at Khodaung is obtained from the intermediate sands on the east flank at depths of 3000 to 4000 feet.

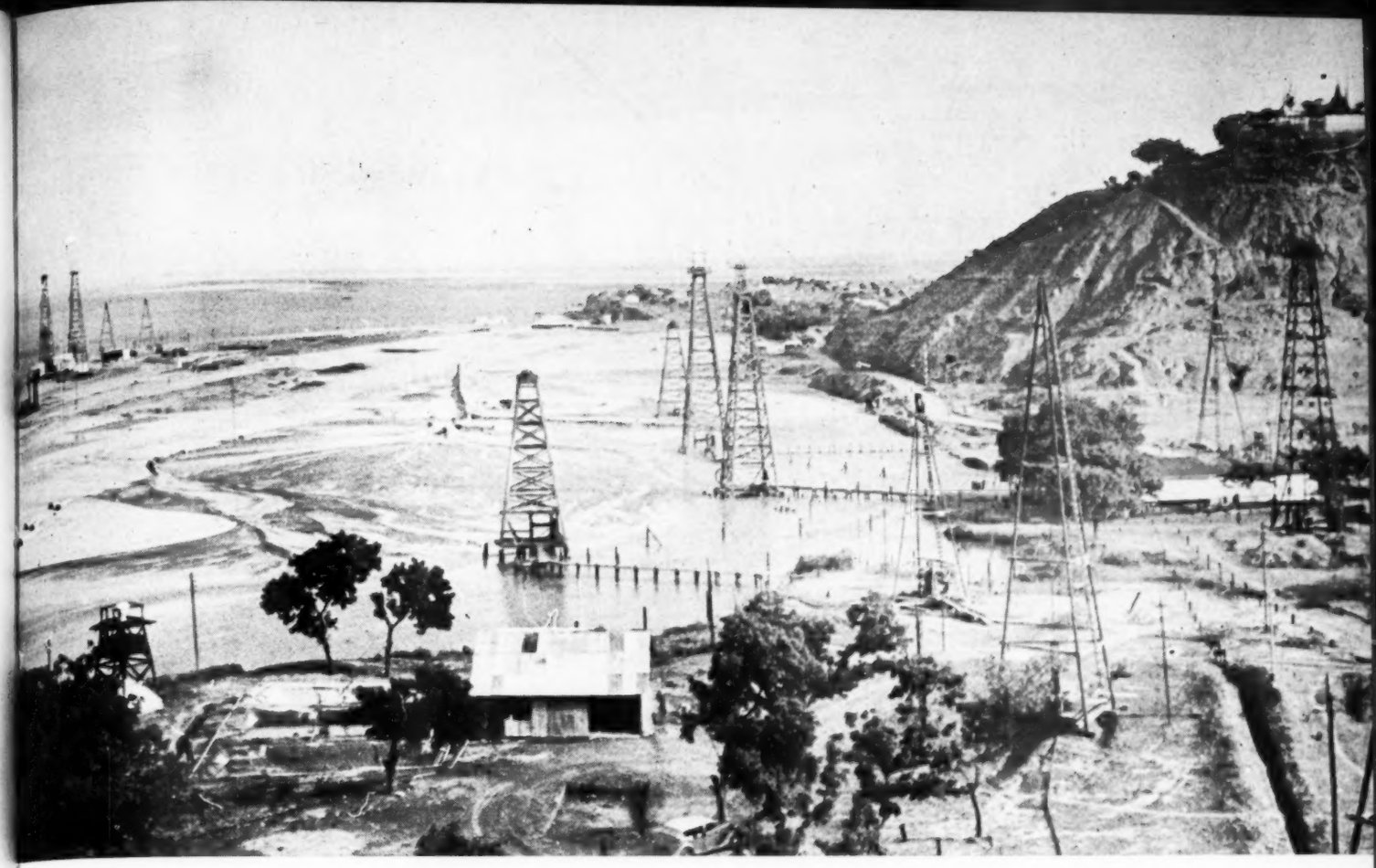
The Yenangyaung (Oil Creek) structure is an asymmetric anticline, its axis extending roughly north and south, parallel to the river. One side dips steeply westward toward the river, the other less steeply eastward. The structure was first exploited more than fifty years ago by Burmese who dug shallow wells by hand and bailed the mixture of oil and water by means of cans and buckets on rattan ropes. Many of these first shallow wells are still in existence and more such wells are completed each year. Some reach depths exceeding 300 ft. but few produce more than five bbl. of fluid daily, 90 percent of which is water.

As a result of this early production practice, the crest of the structure was divided into tracts 60 ft. in circumference all of which have been drilled subsequently with the result that this area probably is the most closely drilled in the world. This area is known, curiously enough, as the "Reserve", having been reserved from the larger mineral grants or leases for individual exploitation.

The total number of wells in the entire Yenangyaung area must exceed 4000 as the Burmah Oil Company has drilled more than 2800, of which about 2300 produce oil. The number of wells owned by Burmese operators is unknown as operations have proceeded for fifty years and few wells are properly abandoned, because of the cost. The average production per well is very small and many wells are pumped intermittently long after they have reached their economic limit of continuous production. For example, the Burmah Oil Company has 250 wells producing less than 0.1 bbl. daily and 600 producing less than 0.5 bbl. daily. The 2300 wells produced in November, 1937, about 8000 U. S. bbl. per day, or approximately 3½ bbl. per day each. Only the very high price re-



Chief producing fields of Burma and Assam



Above—The training wall at Singu, opposite I. B. P. Company's training wall at Lanywa. Recovering oil from river bed

ceived for the refined products, almost $4.00 per U. S. bbl., and the very low costs make such operations possible.

Reservoir Conditions

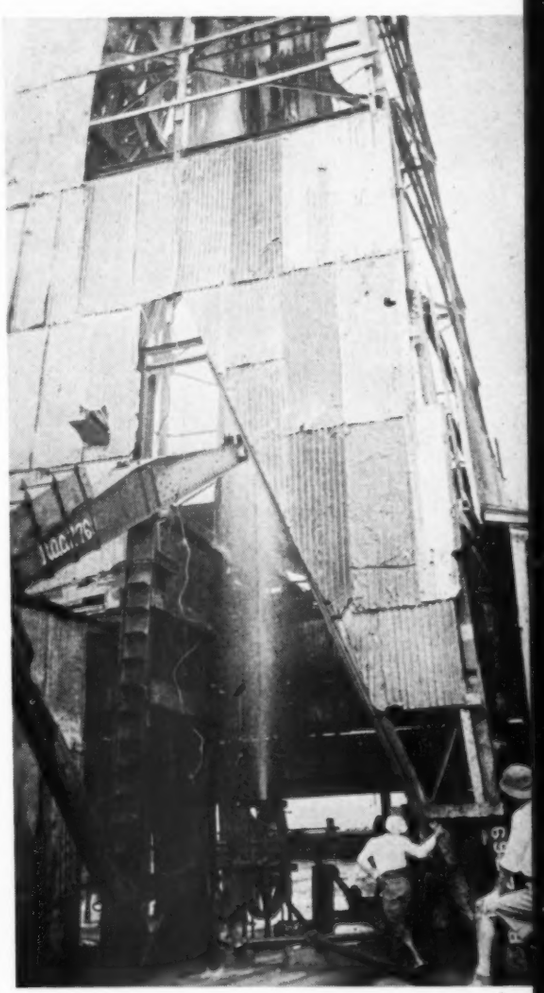
Very few data on characteristics of the Yenangyaung reservoir sands are available. Average porosity seems to be low, probably less than 18 percent, and generally speaking the sands are rather fine grained. The original gas/oil ratio of wells recently completed in the intermediate sands on the east flank is about 800 cu. ft. per bbl. and the average for all wells of the Burmah Oil Company throughout the field is about 1500 cu. ft. per barrel. It is impossible to state whether an original gas cap existed on the Yenangyaung structure or not.

Lateral variation in the texture and thickness of the sands in this area makes correlation difficult. The sands are closely spaced and it is likely that errors in correlation have been caused by the drift of wells during drilling. There are few markers but in general the producing zones have been classified as shallow, intermediate, lower, and deep zones. Two groups of shallow sands at depths of 350 and 650 ft. respectively yield small production. The intermediate sands extend from a depth of approximately 1000 ft. to nearly 2400 ft. at the top of the structure. The lower sands are below this zone and extend to a depth of about 3000 ft., where a strong gas sand is generally found. Production that may be obtained from depths exceeding 3000 ft. would be regarded as coming from a deep zone.

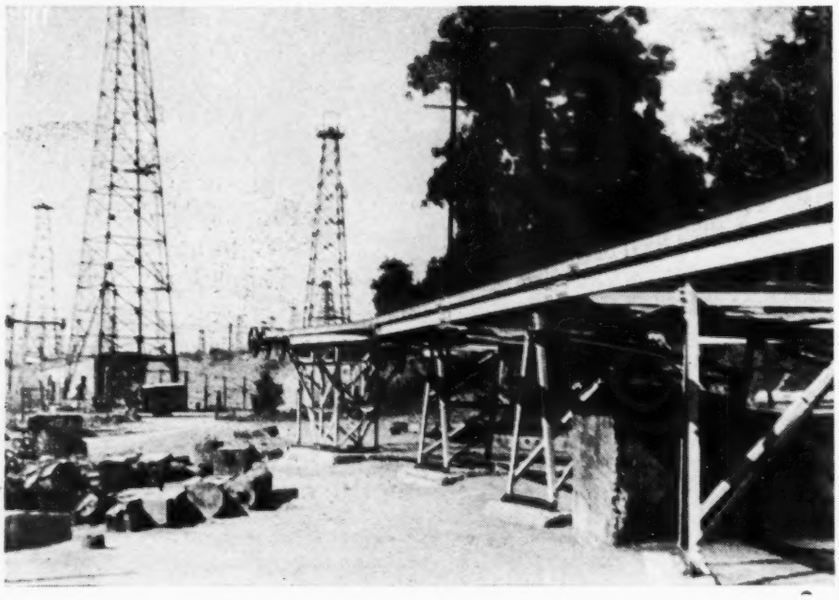
Probably because of a lack of a water drive, formation pressures in the upper and intermediate sands are low. In the opinion of engineers of the Burmah Oil Company, this low formation pressure necessitates completion with cable tools. Wells drilled into the "deep" sands have encountered relatively high pressure but only a small volume of gas.

The absence of any apparent edge water encroachment is somewhat puzzling. The wells on the edge of the field produce both oil and water and their decline is contrary to the usual behavior of wells under hydraulic control. Production curves show the rate of water decline to be slower than that of oil decline.

There has been no successful completion in the so-called "deep" zone and geologists and engineers in the field are unwilling to hazard any opin-



Swabbing-in a 5400-ft. well in the Yenangyaung field



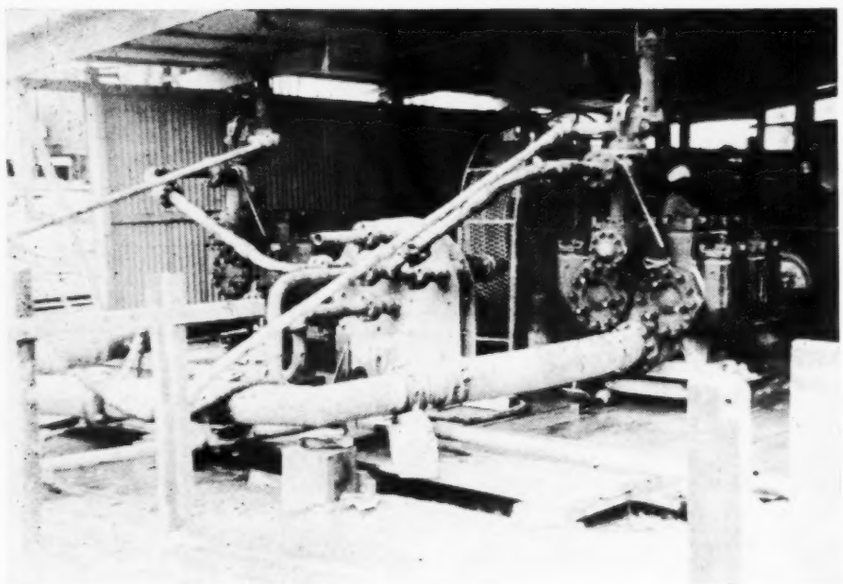
The end of the Burmah Oil Company's aerial tram at Khodaung over which a part of the equipment is transported to the field from Irrawaddy River. Equipment is also transported to the field by truck

ion as to the probability of obtaining production from these sands.

Drilling Methods

In general, the formations at Yenangyaung are hard sandy shale, shale, sand, very tough shale, and intermediate hard shells. In the producing zones much of the formation is sandy shale and thin strata of oil sand, the sand and shale both containing oil. This condition has probably been influential in the use of cable tools for drilling the producing zone. At many locations steep dips are encountered as indicated by the geological features noted.

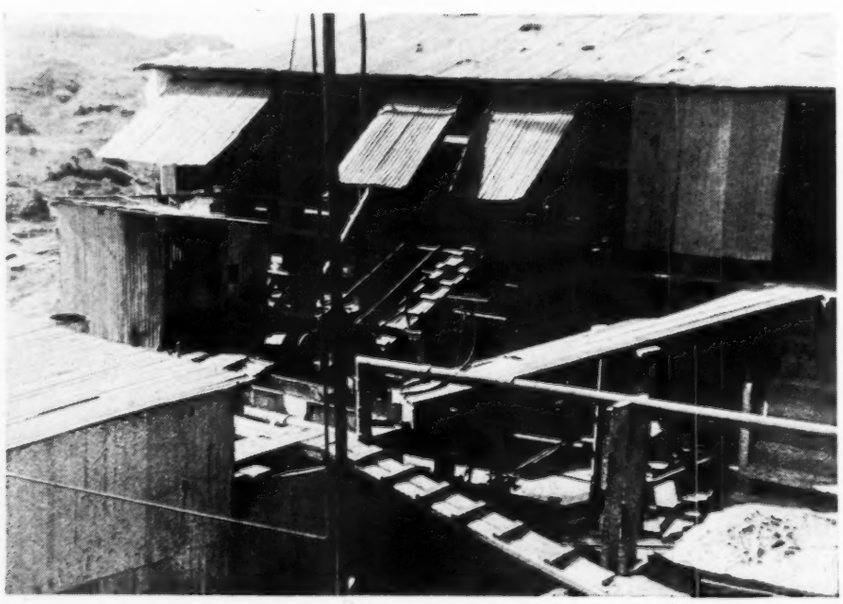
For many years after the English companies started development all wells were drilled with cable tools. When the rotary equipment was introduced the reservoir pressure had been so depleted that completion with rotary tools was unsuccessful so the practice of cable-tool completion was resumed and is rigidly adhered to even



A pump manifold developed by staff members of the Burmah Oil Company and in use in the Singu field, Burma. By rotating spools in the panel in which connections are set, valves can be eliminated

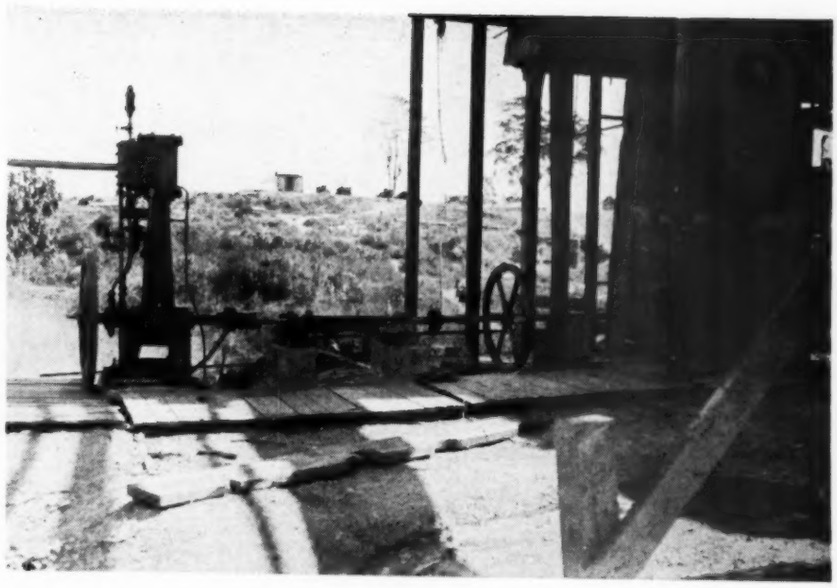
in the flank areas where the pressure is still sufficiently high to make this practice seem quite unnecessary.

Nine strings of cable tools are being used by the Burmah Oil Company for drilling shallow and intermediate wells and for repair work. Shallow and intermediate zones produce considerable water but cementing operations to repair wells involve only low pressure procedure. The operators plan to use five rotary rigs in the main field in addition to the one drilling the deep



A view of the deep test, Well No. 2821, which is being drilled in the Yenangyaung field with steam. All other operations in this field are electrified

On many of the deep tests the master control gate is operated by a steam engine installed for that particular purpose



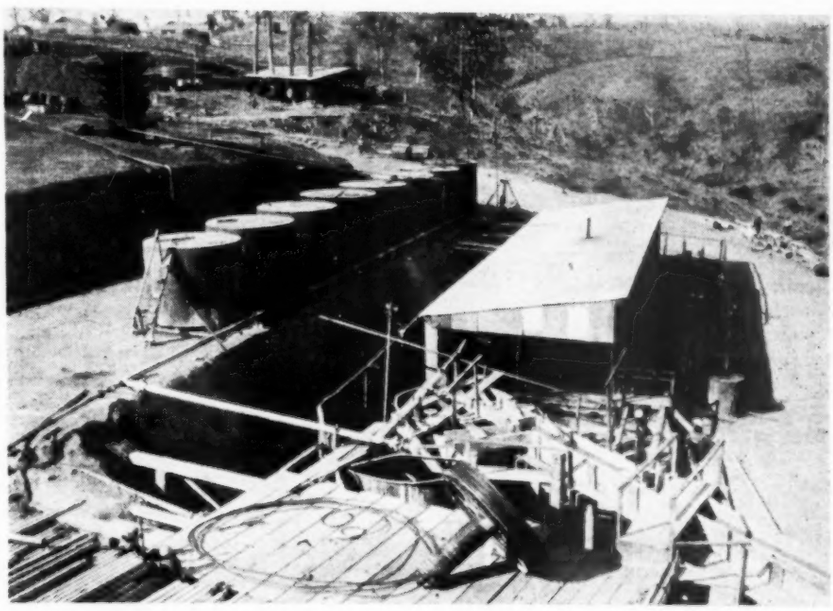
test, which has now reached a depth exceeding 8000 feet.

Modern four-speed rotaries are used by the Burmah Oil Company down to the water shut-off, the usual casing plan being about 400 ft. of 17-in. conductor, a 10¾-in. water string set at depths of 2000 to 3800 ft. depending on structural position, and a full 8⅝-in. string, the bottom of which is perforated. When the desired depth has been reached, the 8⅝-in. string is backed-off from a special adapter nipple and the perforated liner is left resting on bottom. The perforations are commonly round, shop-drilled holes.

The usual practice is to deepen the well at intervals, and the liners are pulled with remarkable ease. It is stated that 300 ft. of liner can always be pulled, and frequently considerably more. When the 8⅝-in. can no longer be pulled, smaller strings are used in deepening the well. No additional cementing is required, as the wells are free from encroaching water.

With the exception of that used on the one deep test, Well 2821, all equipment used is electrical. The Burmah Oil Company operates a large steam tur-

The mud pumps at a wildcat location in the Thayetmyo district

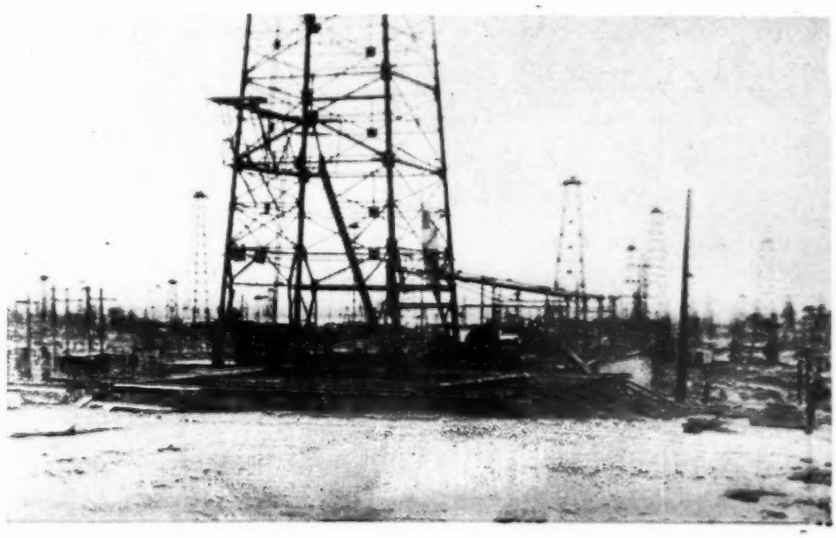


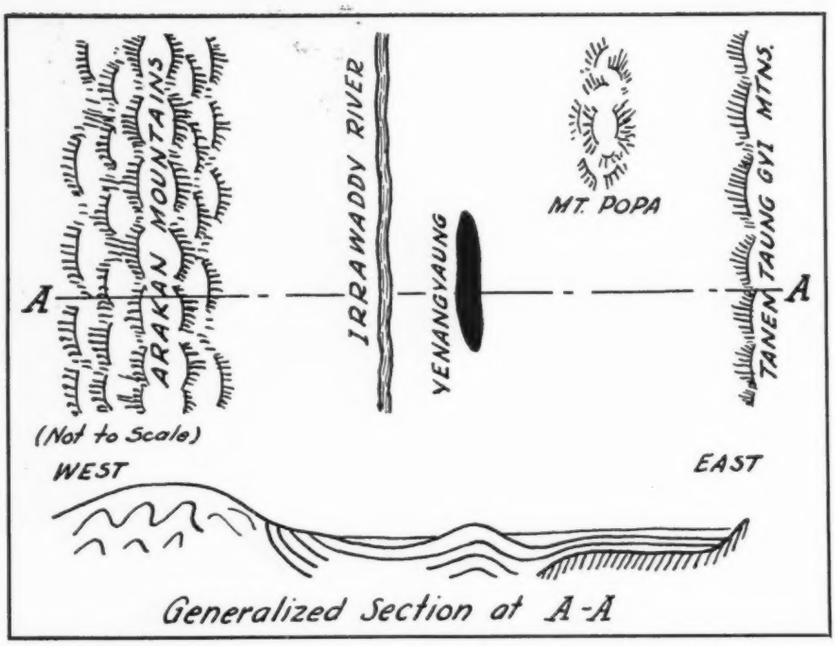
bine electric plant that supplies all companies in the field. A transmission line extends to Singu and all operators there also are supplied with current. The plant is situated on the banks of the Irrawaddy near Khodaung and is said to be highly efficient. Gas from the field is used as fuel.

Some special bits are popular with the drillers and some rock bits are being used. Electrical logging and formation-tester equipment are available but are used less in Yenangyaung than in new areas such as Singu and Yenangyat.

A rotary drilling crew consists of ten men and a cable crew includes

A portion of the later developed area of the Yenangyaung field, Burma





Location and structure of the Yenangyaung field, Burma

eight. Formerly a European or American driller was employed on every tour, but at present the Burmah Oil Company uses only one per well as a considerable number of local Burmese drillers have been trained satisfactorily. The reasons for the substitution are partly economic and partly political and legal. Because of the small stature and light weight of the Burmese and other peoples of the Far East it is common practice not only in Burma but throughout the East to use two men in the derrick. Four or five men work on the floor. One man tends the pumps and on steam rigs one or more firemen are employed depending on the number of boilers. By law one fireman is not allowed to watch more than two boilers.

The only steam rig running in Yenangyaung is the one used on the deep test Well 2821. This is a pressure drilling rig using a hydraulic rotary and externally flush-joint drill pipe. The drill pipe that has been used does not allow for a proper circulation rate even at extremely high pump pressures and a new string of internal and external flush-joint pipe to provide proper circulation is probably in use now. The mud pumps are triple compounded and provided with cast-steel mud ends and can operate at 5000 lb. per sq. inch.

This well reached a depth of 8000 ft. but lost the hole back to the water shut-off at 7200 ft. and was redrilling at 7700 ft. when visited. Many of the difficulties would appear to result from too low a rate of circulation as only about 150 gal. per min. was being pumped during the redrilling operations.

The British Burmah Petroleum Company operates three rotary rigs in the Yenangyaung field. The casing program for rotary wells of this company usually includes an 11¾-in. water string and 8⅝-in. liner. Enlargement of the hole at and just above the shoe for cement is standard practice.

This company owns some 500 wells in the Yenangyaung field from Twingone to Minlindaung. Total production from these wells is 360 bbl. per day, individual wells producing a few gallons to 80 bbl. of oil from depths of 300 ft. to 4700 feet.

One B.B.P. rotary is being used on a redrill exploratory well at Minlindaung. The company is operating four strings of cable tools in shallow wells in the Twingone Area.

The Nath Singh Oil Company produces approximately 200 bbl. of oil per day from 200 wells, which individually produce a few gallons to 40 bbl. from depths of 300 ft. to 4700 feet. All the crude is refined in a modern plant situated on Irrawaddy River at Ngaunghla and the products are distributed by the company's own organization and by local dealers in the vicinity of the fields.

The de-gassing tower for this well, drilled several years ago to a depth of 7220 ft., has never been used. The well will be deepened, however, and the tower stands ready for use

Production Methods

All the producing wells at Yenangyaung are being pumped at present. The new completions no longer flow and the use of gas lift and chamber displacement pumps has been discontinued, although both methods are still in use at Singu. Some twenty years ago the management installed numerous band wheel powers pumping very large numbers of wells, one having 128 wells hooked-on. These powers have proved in many ways to be very unsatisfactory. Too long rod lines, excessive friction, ineffective counterbalancing, and excessive production losses because of down time on large units were the principal faults. A program of construction of small powers pumping 12 to 25 wells has now been planned, and as these powers are completed groups of wells are transferred from the big powers to the new units.

A plunger-lift pump is also being tried at the present time.

As all the present wells are completed with cable tools and the derrick stands motorized, standard ends are used to pump the newer wells. Gradually two- and three-well units are being installed, similar to the back-side-crank outfits in use in California. Several individual well pumping units of conventional types also have been designed and constructed and the Bur-

mah Oil Company is steadily building units in the company shops. Motor drive through V-belt pulley is preferred to reduction gears.

It is asserted that there is absolutely no emulsion trouble and only rarely is there serious wax trouble. Scrapers are run in some wells when rods are pulled in the ordinary course of operations. The oil is moved through a gravity collecting system to the central storage plant at Khodaung and pumped to the refinery at intervals, as capacity of the 10-in. line exceeds the production.

Gas Operations

The casinghead gas is collected and treated in a compression and absorption gasoline extraction plant of a vintage of fifteen years ago. About one-third or one-half the gas produced is burned as fuel at the steam plant and in shop operations, etc. A considerable part of the remaining gas is injected into wells near the flank for repressuring and gas storage. There is great difficulty in preventing by-passing of gas underground and the injection operations are far from satisfactory to the engineers.

SINGU FIELD

The other producing area of importance is that comprising the Singu, Lanywa, and Yenangyat fields. These fields are situated on one geologic structure, a long, asymmetric anticline similar to Yenangyaung, but with the asymmetry reversed, the steep dip here being to the eastward. Irrawaddy River, which is here normally about two-thirds of a mile wide, crosses the structure somewhat north of its center, separating the Singu area on the southeast from Lanywa and Yenangyat on the northwest. Singu is much the most important of the group and produces most of the oil. The town or settlement here is known as Chauk just as the settlement of Yenangyaung is Khodaung.

Singu has been developed by the three larger companies almost entirely. One large block is held jointly by the British Burmah Petroleum Company and Indo-Burma Petroleum Company and is operated by a special subsidiary. The Burmah Oil Company produces more than 8000 bbl. per day, which is more than three-fourths of the total production.

Drilling Methods

The Singu or Chauk field is a reserve and although more than 700 wells have been drilled, approximately 350 are producing. Individual well production ranges from a few gallons to 1600 bbl. per day. Depths range from 1800 to 5000 feet. Six productive zones have been proved but between these there are water-bearing strata.

As at Yenangyaung, electric power is used for virtually all operations. The current is brought from the power plant near Khodaung by a 40-mile transmission line. The original plan was to erect power plants at both Khodaung and Chauk and to connect these by a line through which current might be transmitted in either direction as power requirements or fuel gas supply might determine. The two fields are, however, connected by a gas line and current generation is centralized at the one plant.

The Burmah Oil Company is using two rotary rigs and two strings of cable tools. In any further extensions of the field in addition to the area now active on the southeast side, the company would follow its usual procedure and drill a double line of offset wells.

Drilling methods are similar to those in the older field, the wells being completed with cable tools despite relatively high pressure and large initial production. One difference that might be noted is the greater care taken in cement jobs, Aquagel being used by the Burmah Oil Company on all water jobs and occasionally on a lost circulation job. Cane bagasse from sugar factories in Central Burma is also used to regain lost circulation.

Because of the presence of highly corrosive top and surface waters great care has been taken recently to protect the water string by cementing to the surface and it is expected that gel cements will be used in the future for this purpose. This procedure has been in vogue for several years. The casing in wells drilled previously is being renovated and a protective string of 8⅝-in. casing set to the shoe of the 10⅜-in. string and cemented solid to the surface.

The well spacing is much more moderate here because of the larger blocks but the field is overdrilled in spots because of failure of operators to negotiate offset agreements. The southern plunge of the structure is much less productive, recent completions having initial production rates of scarcely 100 bbl., whereas new wells close to the river have rates as great as 800 barrels.

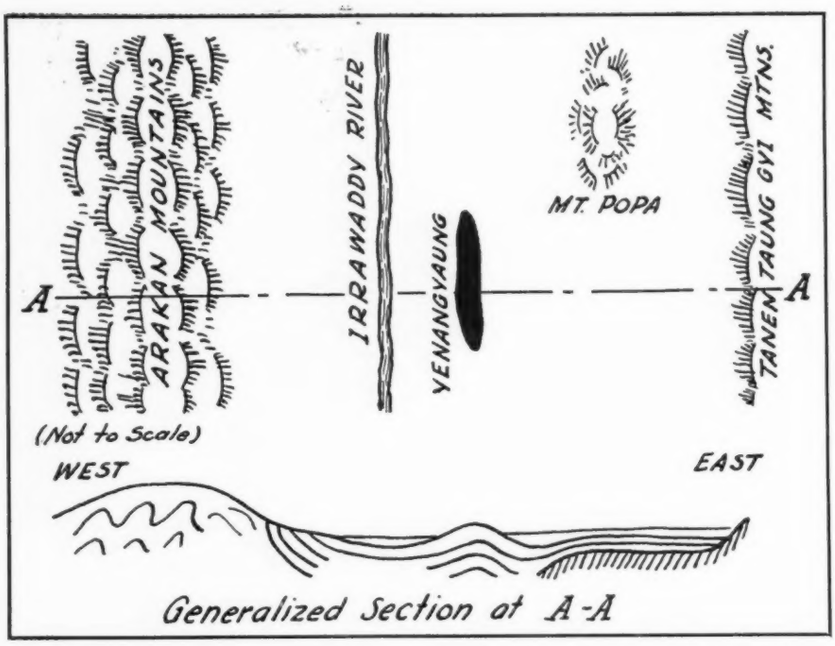
The river cuts a band two-thirds of a mile wide across what is believed to be the best part of the structure. The Burmah Oil Company has built a wall or jetty into the river along its property line and crowded it with wells but the bed of the river proper belongs to the companies on the Lanywa side. Unless some further agreement is negotiated the river bed must be developed by slant drilling as the Irrawaddy is a navigable stream and the Burmese Government will not allow islands to be built.

The Indo-Burma Petroleum Company had previously built a retaining wall one and one-half miles long on the west bank of the river in order to enable drilling a portion of the structure lying under the river. This project was so successful that the B.O.C. then built the wall on the east bank. A well recently completed close beside this wall flowed 1600 bbl. per day from a depth of 2600 ft. at a casinghead pressure of 600 pounds.

Production Practice

Many of the wells are still flowing and many more are on gas lift, either continuous or intermittent. As no gas is used as fuel, all power being obtained from the steam turbine plant at Khodaung, a large surplus of gas exists and considerable attention is being paid to gas injection to maintain pressure. The records to date do not show any pronounced effect on production resulting from the injection but in the absence of other beneficial uses for the gas it will undoubtedly be continued. Production practice in general is similar to that at Yenangyaung, the depth of the wells and the gravity

Cleaning by hand a hand-dug shallow well in the Yenangyaung field



Location and structure of the Yenangyaung field, Burma

eight. Formerly a European or American driller was employed on every tour, but at present the Burmah Oil Company uses only one per well as a considerable number of local Burmese drillers have been trained satisfactorily. The reasons for the substitution are partly economic and partly political and legal. Because of the small stature and light weight of the Burmese and other peoples of the Far East it is common practice not only in Burma but throughout the East to use two men in the derrick. Four or five men work on the floor. One man tends the pumps and on steam rigs one or more firemen are employed depending on the number of boilers. By law one fireman is not allowed to watch more than two boilers.

The only steam rig running in Yenangyaung is the one used on the deep test Well 2821. This is a pressure drilling rig using a hydraulic rotary and externally flush-joint drill pipe. The drill pipe that has been used does not allow for a proper circulation rate even at extremely high pump pressures and a new string of internal and external flush-joint pipe to provide proper circulation is probably in use now. The mud pumps are triple compounded and provided with cast-steel mud ends and can operate at 5000 lb. per sq. inch.

This well reached a depth of 8000 ft. but lost the hole back to the water shut-off at 7200 ft. and was redrilling at 7700 ft. when visited. Many of the difficulties would appear to result from too low a rate of circulation as only about 150 gal. per min. was being pumped during the redrilling operations.

The British Burmah Petroleum Company operates three rotary rigs in the Yenangyaung field. The casing program for rotary wells of this company usually includes an 11¾-in. water string and 8⅝-in. liner. Enlargement of the hole at and just above the shoe for cement is standard practice.

This company owns some 500 wells in the Yenangyaung field from Twingone to Minlindaung. Total production from these wells is 360 bbl. per day, individual wells producing a few gallons to 80 bbl. of oil from depths of 300 ft. to 4700 feet.

One B.B.P. rotary is being used on a redrill exploratory well at Minlindaung. The company is operating four strings of cable tools in shallow wells in the Twingone Area.

The Nath Singh Oil Company produces approximately 200 bbl. of oil per day from 200 wells, which individually produce a few gallons to 40 bbl. from depths of 300 ft. to 4700 feet. All the crude is refined in a modern plant situated on Irrawaddy River at Ngaunghla and the products are distributed by the company's own organization and by local dealers in the vicinity of the fields.

The de-gassing tower for this well, drilled several years ago to a depth of 7220 ft., has never been used. The well will be deepened, however, and the tower stands ready for use

Production Methods

All the producing wells at Yenangyaung are being pumped at present. The new completions no longer flow and the use of gas lift and chamber displacement pumps has been discontinued, although both methods are still in use at Singu. Some twenty years ago the management installed numerous band wheel powers pumping very large numbers of wells, one having 128 wells hooked-on. These powers have proved in many ways to be very unsatisfactory. Too long rod lines, excessive friction, ineffective counterbalancing, and excessive production losses because of down time on large units were the principal faults. A program of construction of small powers pumping 12 to 25 wells has now been planned, and as these powers are completed groups of wells are transferred from the big powers to the new units.

A plunger-lift pump is also being tried at the present time.

As all the present wells are completed with cable tools and the derrick stands motorized, standard ends are used to pump the newer wells. Gradually two- and three-well units are being installed, similar to the back-side-crank outfits in use in California. Several individual well pumping units of conventional types also have been designed and constructed and the Bur-

mah Oil Company is steadily building units in the company shops. Motor drive through V-belt pulley is preferred to reduction gears.

It is asserted that there is absolutely no emulsion trouble and only rarely is there serious wax trouble. Scrapers are run in some wells when rods are pulled in the ordinary course of operations. The oil is moved through a gravity collecting system to the central storage plant at Khodaung and pumped to the refinery at intervals, as capacity of the 10-in. line exceeds the production.

Gas Operations

The casinghead gas is collected and treated in a compression and absorption gasoline extraction plant of a vintage of fifteen years ago. About one-third or one-half the gas produced is burned as fuel at the steam plant and in shop operations, etc. A considerable part of the remaining gas is injected into wells near the flank for repressuring and gas storage. There is great difficulty in preventing by-passing of gas underground and the injection operations are far from satisfactory to the engineers.

SINGU FIELD

The other producing area of importance is that comprising the Singu, Lanywa, and Yenangyat fields. These fields are situated on one geologic structure, a long, asymmetric anticline similar to Yenangyaung, but with the asymmetry reversed, the steep dip here being to the eastward. Irrawaddy River, which is here normally about two-thirds of a mile wide, crosses the structure somewhat north of its center, separating the Singu area on the southeast from Lanywa and Yenangyat on the northwest. Singu is much the most important of the group and produces most of the oil. The town or settlement here is known as Chauk just as the settlement of Yenangyaung is Khodaung.

Singu has been developed by the three larger companies almost entirely. One large block is held jointly by the British Burmah Petroleum Company and Indo-Burma Petroleum Company and is operated by a special subsidiary. The Burmah Oil Company produces more than 8000 bbl. per day, which is more than three-fourths of the total production.

Drilling Methods

The Singu or Chauk field is a reserve and although more than 700 wells have been drilled, approximately 350 are producing. Individual well production ranges from a few gallons to 1600 bbl. per day. Depths range from 1800 to 5000 feet. Six productive zones have been proved but between these there are water-bearing strata.

As at Yenangyaung, electric power is used for virtually all operations. The current is brought from the power plant near Khodaung by a 40-mile transmission line. The original plan was to erect power plants at both Khodaung and Chauk and to connect these by a line through which current might be transmitted in either direction as power requirements or fuel gas supply might determine. The two fields are, however, connected by a gas line and current generation is centralized at the one plant.

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Drilling methods are similar to those in the older field, the wells being completed with cable tools despite relatively high pressure and large initial production. One difference that might be noted is the greater care taken in cement jobs, Aquagel being used by the Burmah Oil Company on all water jobs and occasionally on a lost circulation job. Cane bagasse from sugar factories in Central Burma is also used to regain lost circulation.

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Cleaning by hand a hand-dug shallow well in the Yenangyaung field

of the oil being about the same in the two areas.

Operations Southeast of Chauk

Near Negya, five miles southeast of Chauk, in what may be considered an extension of the Singu or Chauk field, the Burmah Oil Company has a contract agreement to drill, produce, and buy crude on the Moola Oil Company property. This property is adjacent to holdings of the Pyinma Development Company, Ltd., British Burmah Petroleum Company, and Nath Singh Oil Company.

The B. O. C. operates about 50 producing wells here. The one most recently completed had an initial production of 300 bbl. per day and is the best well drilled yet by this company. The producing depths range from 3800 to 5000 ft. and initial production from the line wells has ranged from 150 to 200 bbl. per day.

On the adjacent property of the Pyinma Development Company, Ltd., initial production has ranged from 200 to 800 bbl. per day. These wells have three producing zones: the "C" zone at a depth of 3800 ft., which is 15 ft. thick; the "P.D.C." at 3900 ft., which is 20 ft. thick, and the Moola at 4700 ft., which is 40 ft. thick. On the Moola property being drilled by B.O.C. the upper two zones are barren. Some of the zones in this area produce water.

The Pyinma Development Company, Ltd., is a joint venture of Indo-Burma Petroleum Company, Ltd. and British Burmah Petroleum Company, Ltd. Although Steel Brothers are the agents for I.B.P., the B.B.P. is represented by its local agents. The I.B.P., however, actually controls and directs developments from Lanywa.

About 30 wells have been drilled on this property. The present production is 1000 bbl. per day but the operators desire to increase it to 1200 bbl. per day. Although the wells usually flow for some time, the production declines moderately, and they produce 30 to 80 bbl. per day on the pump. The gravity of the oil is 36 to 42 deg. A.P.I.

The usual casing program includes an 8⅝-in. water string and 6⅝-in. liner but sometimes 11¾-in. and 8⅝-in. are substituted. Two unitized steam and one electric drawworks are in operation. The pumps are 7¼ in. by 14 in. by 14 inch. Fishtail and special bits are widely used but rock bits, which have been used to some extent, are meeting with increased approval. One cable-tool rig is employed for drilling-in.

Unless water trouble increases, two completions per month are contemplated. There is a large proved area to be developed and it is the company's desire to maintain production by drilling new wells.

British Burmah Petroleum Company operates 60 wells in the Negya area and they produce 200 bbl. per day from depths of 3000 to 3800 feet. On a half-block proved by P.D.C. one well was recently completed at a depth of 4500 ft. and had an initial production of 250 barrels. This has now settled to 150 bbl. per day.

The B.B.P. has a half interest in the P.D.C. production, so with its own crude it has an ample supply for present needs. The B.B.P. has only one rotary rig at Chauk and it is being used to test a structure in the main field. The company is endeavoring to arrange for a further outlet for refined products in western India but competition for that market has been increased by the entry of Bahrein products.

Should the P.D.C. and the Nath Singh Oil Company prove larger areas adjacent to the half-block mentioned, the B.B.P. will be obligated to protect its property by offset drilling. It has no specific drilling program at the present time but greater activity may be necessary later as conditions change, if from no cause other than the natural decline of production from existing wells, which is moderately fast in this particular area.

LANYWA FIELD

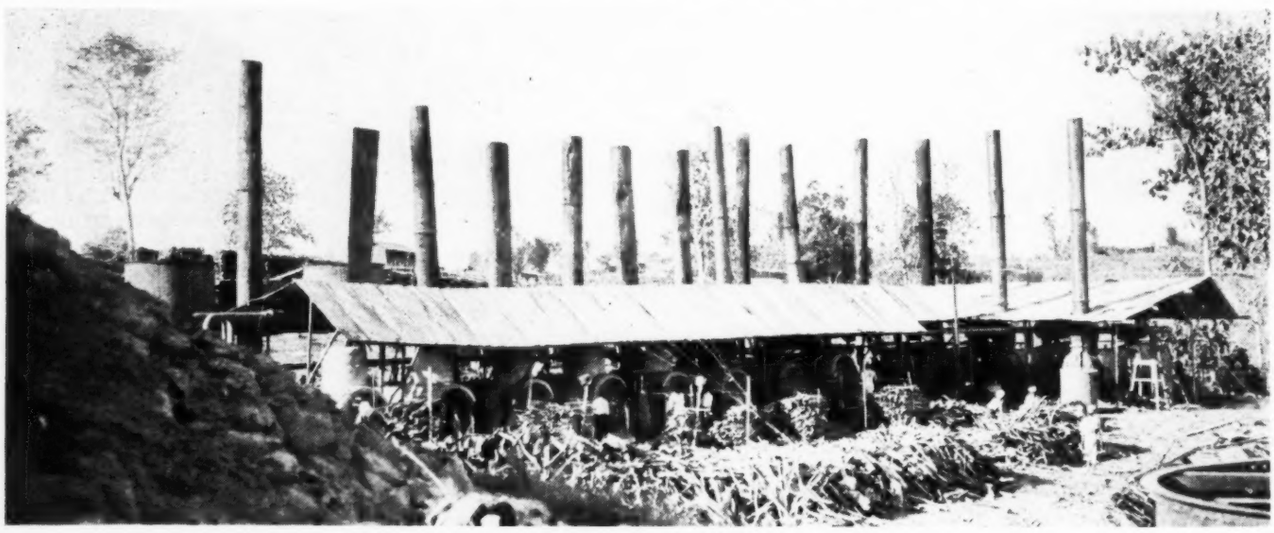
This is a semi-reserve field held by the Indo-Burma Oil Company, Ltd., for which Steel Brothers are managing agents. The field is virtually a northwest extension of the Singu field and the I.B.P. lease covers the bed of Irrawaddy River southeastward to the Burmah Oil Company wall on the east bank of the river. The structure extends about two miles northwest of the I.B.P. wall on the west bank of the river and has a width of one-half mile.

Production is approximately 1300 bbl. per day from 80 wells. The crude is transported by river to the company's refinery at Rangoon. Most of the wells are being pumped and the gas pressure is low. Depths range from 1700 to 3200 ft., several productive zones existing between those depths. Water troubles are negligible.

This field is also electrified but the current for operations is generated by gas engines consuming gas from the field for fuel.

The casing program consists normally of an 8⅝-in. water string and 6⅝-in. liner but in some wells the

A battery of boilers at the Monatkon Test. Note the wood piled ready to be used as fuel to fire the boilers.



Looking downward from the top of the derrick of the Monatkon Test. To the right can be seen a large supply of wood piled around the camp for use in firing the boilers.

water string is 11¾-in. and the liner 8⅝-inch. All wells are drilled-in by cable tool. The standard practice in cementing the water string is to use cement equalizing guides, a guide shoe, and a float collar.

One rotary rig is working on a directionally-drilled well close beside the retaining wall. The intention is to complete this hole under the river in line with the large well recently completed by B.O.C. on the east bank of the river. Directional-drilling equipment includes underground surveying instrument, knuckle joint, whipstocks, and bits of the types usually employed on such jobs.

YENANGYAT FIELD

The sharply asymmetric anticline from which oil is produced includes both the Yenangyat and Sabe fields and the two crests are structurally continuous with that at Singu. Wells in the Sabe area are not now producing and operations at present are limited to Yenangyat. Only the lower producing sands of Singu are included in this section so the potential production from known zones is smaller.

Yenangyat field is characterized by extremely rough topography; many well locations are difficult to clear and much expensive grading is necessary. A moderate application of slant drilling practices would probably simplify the problem.

Approximately 450 wells have been drilled, in addition to the Burman hand-dug wells, some of which still produce. The structure is very narrow and extends from Sabe, nine miles northwest of Yenangyat, to a point eight miles south of Yenangyat in the direction of Lanywa and Chauk. The present operations are those of the Burmah Oil Company but the British Burmah Petroleum Company owns several tracts west and one south of the present producing area.

Production from Yenangyat is normally about 500 bbl. of 32- to 60-deg. A.P.I. gravity oil per day from 250 wells. Production from individual wells ranges from a few gallons to 60 bbl. per day. Upon completion, some wells flow as much as 200 bbl. per day. Water causes no particular problem, although in some wells water accompanies the oil.

The drilling depths range from 400 to 4200 ft., the average being approximately 2000 feet. The thickness of the producing zone varies from 100 to 150 feet.

The casing program now being followed consists of a 6⅝-in. water string and 4½-in. liner. One rotary rig is being used to drill at depths exceeding 3000 ft., and four strings of cable tools are used to drill the shallow and intermediate wells.

INDAW FIELD

This field in the Upper Chindwin District is the most northerly of the Burmese fields and is held under lease by the Indo-Burma Petroleum Company. Because the field is about 20 miles east of Chindwin River nearly 300 miles from its junction with Irrawaddy River it is almost inaccessible, and great difficulties have been overcome in its development. Only stern-wheel steamers of shallow draft can navigate the river and the area is almost without roads. Heavy equipment can be transported only with considerable difficulty. During the monsoon season, sudden disastrous floods hamper operations.

The structure is a low dome. At present I.B.P. is producing more than 200 bbl. per day of 36- to 42-deg. gravity oil from 80 wells. An automatic gas-lift system is now in operation. The oil was formerly refined at a small refinery at Pantha on Chindwin River as Upper Burma was the chief market for kerosene. This refinery is no longer operated. The oil produced at Indaw is now stored at the field during low-water season and then during high water is piped to the river and transported by barge steamer to the company's refinery at Rangoon.

Wells in the Indaw field are drilled by cable tool and average slightly more than 2000 ft. in depth. One string of tools is drilling new wells to maintain production. High gas pressures make deep drilling difficult so only the shallow sands have been explored. In addition, the difficulty of getting equipment to the field has probably retarded development.

Burmah Oil Company is drilling a rotary test known as the Yenan Test in the Chindwin District and this well has encountered some favorable showings. Operations are suspended before the rainy season and are resumed when the rains stop. This well is on the west side of Chindwin River.

THAYETMYO DISTRICT

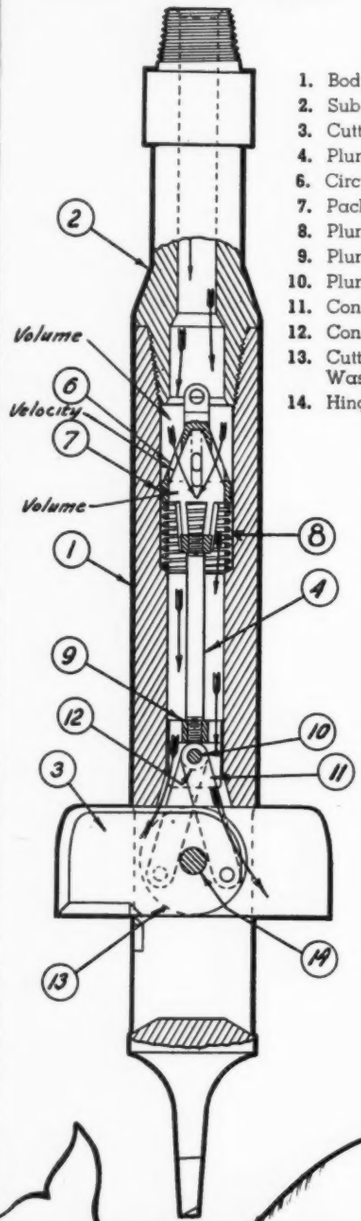
This district is approximately on the border line between the wet zone and dry zone in Lower Burma. Although much exploratory work has been done in this area and there are small producing fields at Yenanma and Padaukpin, the production is not important. There seems to be little prospect of large production from either field by ordinary methods but Bradshaw[1] suggests the possibility of exploiting the shallow sands by mining.

From the two fields, originally developed by Indo-Burma Oilfields, Ltd. (not to be confused with Indo-Burma Petroleum Company) the reorganized Yenan Mines, Ltd., produces 200 bbl. of 45-deg. gravity oil per day, which is sold to Burmah Oil Company. All wells are shallow cable-tool holes ranging from 600 to 1700 ft. in depth. The deepest well was drilled to 2500 feet. Individual well production ranges from 1 to 40 bbl. per day.

The extensive holdings of this com-

[1] "Petroleum in the Indian Empire," by Eric J. Bradshaw. Transactions Petroleum Division A.I.M.E., 1931.

IT'S A WHALE OF A TOOL!



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2. Sub.
3. Cutter Blades
4. Plunger Rod
6. Circulation Control Head
7. Packing Ring
8. Plunger Spring
9. Plunger Link Head
10. Plunger Link Pin
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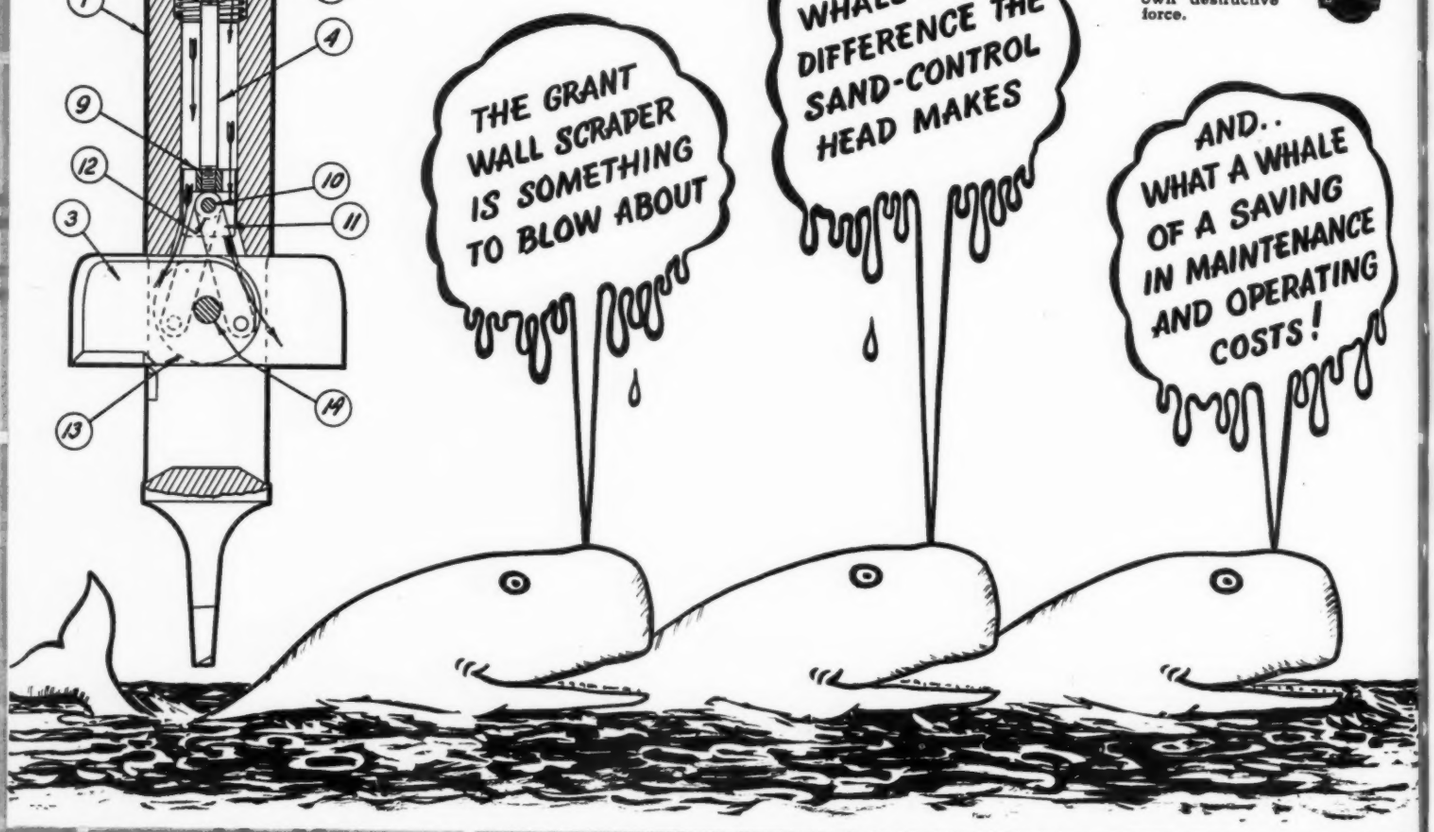
THE GRANT WALL SCRAPER IS SOMETHING TO BLOW ABOUT
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pany in the Thayetmyo District comprise old P.O.C. and I.B.O. quit-claimed properties. Although the company is not opulent, it intends to explore and to seek deeper oil zones. It may decide on the use of a light, portable rotary outfit within the next year for this purpose.

In the Thayetmyo District the Burmah Oil Company is drilling a well known as the Monatkon Test. This was drilled to a depth of 8200 ft. but was plugged-back and is now being tested. This test is in the wet zone so operations cease with the arrival of the rains. It is on a large concession, which will receive further exploration.

At Pyayé, eight miles south of Thayetmyo, the Indo-Burma Petroleum Company has a dry gas field in which four wells were drilled by cable tools to a depth of 2600 feet. Two of these wells each produce 8,000,000 cu. ft. or more and a cement company is using 1,500,000 cu. ft. daily for its operation. A deep rotary test is now being drilled and the gas is used for fuel in the boilers supplying the steam. This well-equipped test will be drilled to a depth of 9,000 or 10,000 ft. and provisions have been made for controlling any high pressures that may be encountered. The company has several square miles in this area.

MINBU FIELDS

In this area are situated the "down-river fields" of Minbu Town, Palanyôn, and Yethaya, which are separate pools but are generally grouped together. They are situated along the crest of an anticline similar to the Singu-Lan-ywa-Yenangyat anticline, steeply asymmetric and locally overturned. The productive area is very narrow. At Palanyôn and Yethaya the producing sands are comparatively deep. The shallow sands at Minbu Town (Shwelinban) have produced a small but steady supply of oil, and production has been sustained because of structural conditions.

The Burmah Oil Company has exploited the fields with maximum economy. Production has now declined to approximately 250 bbl. per day and most of the oil comes from the shallow wells. These wells are drilled with portable equipment, which is taken away as soon as the well begins to produce. Although the producing wells are closely spaced there are no derricks visible. The wells are pumped by jacks operated by central powers.

Leya-Okpo Field

Forty miles northwest of Pakokku, and between Chauk and the Indaw field, the Nath Singh Oil Company is drilling a cable-tool well. At last report 6⅝-in. casing was being carried at a depth of 850 feet. Several years ago the father of the present Nath Singh held several blocks in this area and drilled a well that had an initial production of 90 bbl. per day of excellent oil from a depth of 750 feet. This well is now producing only a few barrels daily and portions of the lease have been surrendered until only about 1000 acres remain. A 6-in. pipe line connects the field to Pakokku.

The company intends to test the structure by the well now drilling and by others to be drilled at other locations in the vicinity. A cable-tool core barrel will be used for coring so that geological data can be obtained.

Akyab and Kyaukpyu

There is little prospect of important production being obtained at Akyab, directly west of Minbu, or at Kyaukpyu, directly west of Thayetmyo on the Bay of Bengal. Concerning these areas, Bradshaw states[1] "For many years the existence of oil deposits has been known, though the extent of the accumulations has been uncertain. A great deal of exploratory work has been carried out, both by geological reconnaissance and by testing with the drill, without the discovery of any really important accumulations. Oil seepages occur both on the mainland and on the islands off the Arakan coast, particularly on Eastern Baronga Island near Akyab, and on Ramri Island in the Kyaukpyu district. For many years a small indigenous industry has existed, the oil being won from shallow wells sunk by a method of primitive pole-drilling which is none the less more elaborate than the Burmese system of digging wells by hand.

"The oil occurs in beds which are apparently of Nummulitic age; the structure is unfavorable for the existence of large accumulations of petroleum because the folds are acute and close together. Production from Akyab, never great, has steadily declined to negligible proportions, though that from the Kyaukpyu district has been better maintained."

BURMA—PAST AND FUTURE

The entire area of Burma probably has been explored for petroleum accumulations more thoroughly than any other part of the world. Geology, geological mapping, coring, and, to a very great extent during the last few years, geophysics have all been employed in the search for oil. Much of the work has been unrewarded, but although reserves have not been greatly increased, a long period of sustained production at the present rate can be expected because of the conservative development of the known resources

Of particular interest at the present time, however, is the unexpected extension of the existing fields and the consistent increase of production during the last few years. It is true that no entirely new fields have been discovered but the extensions now being developed and the outlook for deeper production in many areas make the future for Burma's oil production bright. It is the opinion of many engineers who have long served in Burma that "only the surface has been scratched." The deep tests now being drilled and the prospects of getting more heavy and modern equipment into service indicate that the optimism is well-founded.

Plaque commemorating the first well drilled by the Burmah Oil Company in the Khodaung field

Importance of Properly Prepared Drilling Fluid Recognized by Operators in Burma

All mud is carefully mixed, tested, and chemically treated

By JOHN F. DODGE and WALLACE A. SAWDON

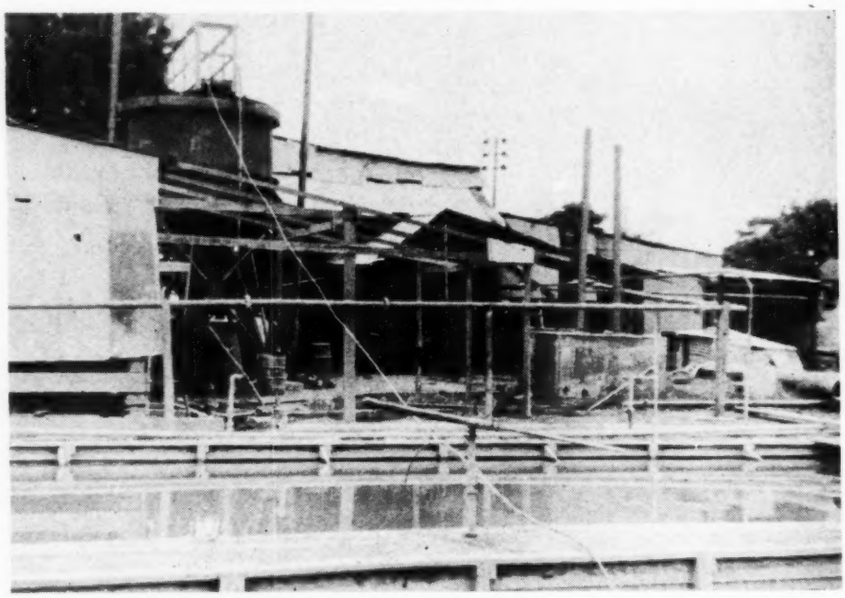
THE mud used in the Yenangyaung and Singu fields is made of a local shale known as Singu shale, which is taken from pits on the bank of Irrawaddy River in the heart of the Singu field. Before the building of the wall at Singu this shale was taken from a pit that was submerged during periods of high water, because shale from this source was found to be superior to the shale dug from the same bed above high-water-level. It was supposed that a base exchange had taken place between the shale and the river water, the pH of which sometimes is less than seven, but this has now been disproved. When the wall at Singu was built the river pit was covered by the back-fill and shale is now dug from pits as close to the river bank as possible.

Complete dispersion of this shale requires a longer time but eventually the quality is about the same as that of the other shale. This shale is quarried, air-dried in heaps under cover, crushed, ground in a small hammer mill, and sent to the wells in sacks containing 80 to 100 pounds. It absorbs some moisture and is handled like cement. J. T. Evans has written a paper on "Preparation and Control of Mud Fluid for Pressure Drilling Conditions," which was read before the Institution of Petroleum Technologists (now The Institute of Petroleum) in May, 1937, and published in the June issue of the institution's journal. This paper gives some data on the use of this mud as a base for weighted muds.

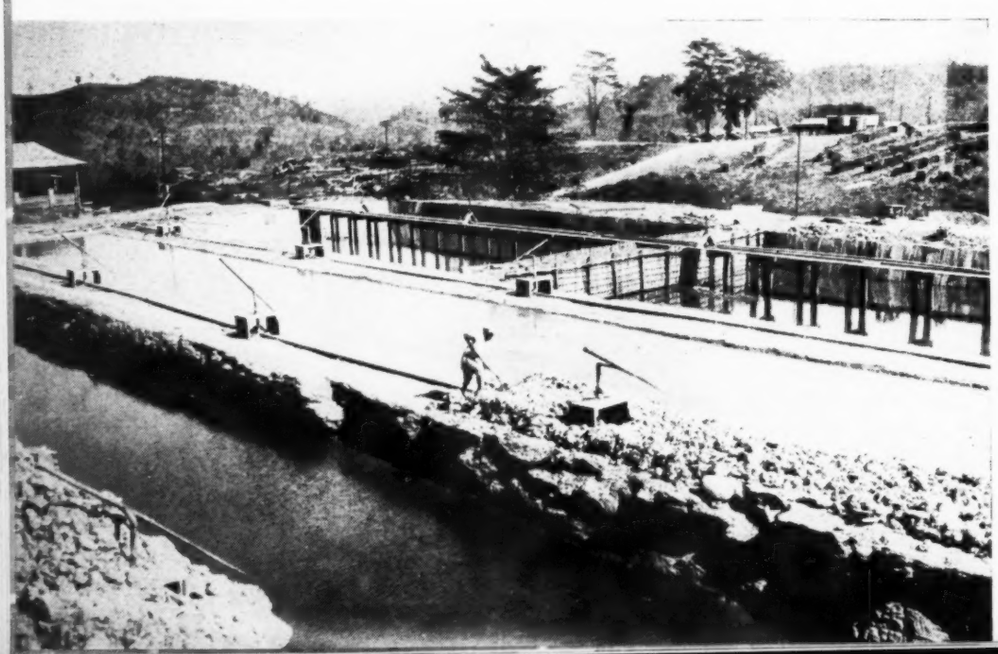
Mixing

The mud is mixed at the well in cone-type jet mixers. An 80-lb. mud containing 40 percent solids by weight is commonly made, but sometimes an 88-lb. mud containing 50 percent solids by weight is made. The 80-lb. mud has a viscosity of 100 Digboi units and the 88-lb. mud, 250 Digboi units. For ordinary drilling, operators prefer a mud having a viscosity of 50 to 60 D. U., which apparently they correlate with 15 to 20 Stormer centipoises. It is stated that a viscosity of 200 D. U. is equivalent to one of 40 to 50 centipoises on the Stormer instrument. The heaver muds are all treated frequently to reduce viscosity.

If weight in excess of 85 lb. is needed, as for pressure-drilling, the mud is weighted with barytes from Madras. This is apparently a high-grade product, as it is asserted to have an average specific gravity of 4.3 and more than 95 percent passes through the 300-mesh screen when it is air-classified. Its cost varies somewhat, depending upon the method of transportation, but averages 35 rupees



Above—A part of the central mud-treating plant in the Yenangyaung field, Burma. Hydraulic cone classifiers for sand separation can be seen at left



Left—Even on deep-test operations in unproved territory extensive mud pits are constructed. The well location is south of the Yenangyaung field

Many years successful performance of Hyatt equipment in the large **WEBER ENGINES** induced the Weber Engine Company to standardize on Hyatts for similar dependability in this smaller addition to their famous line of engines.

Evidence of Hyatt reliability is found everywhere. In service on wheels, on shafts, and gears, Hyatt Roller Bearings are sturdy, smooth and quiet . . . faultless in design and workmanship, carefree in operation. The millions of Hyatts applied each year to new equipment roll on unheeded, except by the engineers, who have learned to specify and depend on Hyatt Roller Bearings. Hyatt Bearings Div., General Motors Corp., Harrison, N. J.; San Francisco. Hyatt Roller Bearing Sales Company, Chicago and Pittsburgh.

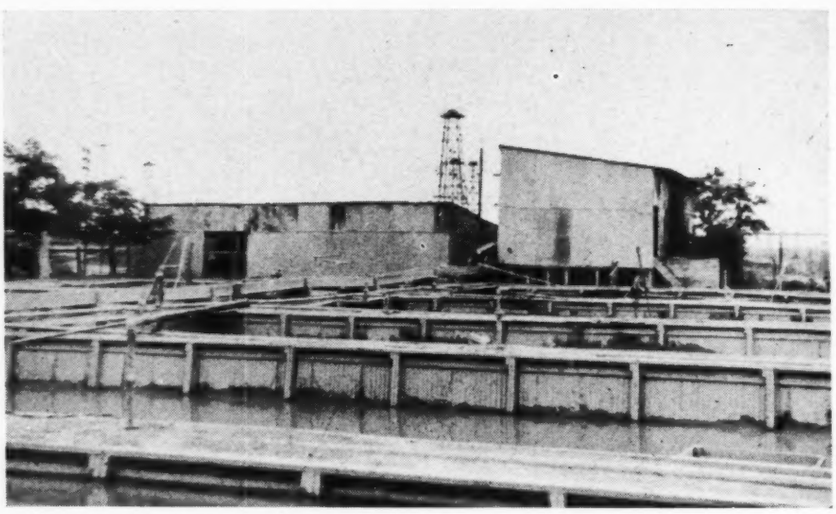
HYATT *Roller* BEARINGS

Sand separators or mud classifiers in tanks of the Burmah Oil Company, Yenangyaung field, Burma

($13.50) per ton f.o.b. Burma fields, which seems to be very cheap, considering the quality of the product. In Well No. 2821, 135 long tons was used in making 900 Burma bbl. of 120-lb. mud, 85-lb. Singu shale mud being used as a base.

Mud Circulation

All wells with the exception of the deep test well, No. 2821, are being drilled entirely with electrical equipment. Drilling fluid in Well No. 2821 is circulated by a battery of steam pumps specially built of semi-steel to provide a maximum working pressure of 5000 lb. per sq. in. when triple-compounded. When drilling at a depth of 7600 ft., the pump pressure was 2500 lb. per sq. in. against 600 lb. per sq. in. back pressure. The circulation rate, however, was only about 140 Imperial gal. per minute. No mud



Mud storage pits at a central mud-treating plant

screens are used ordinarily, the normal installation being three settling tanks each containing a spiral classifier (as shown in the accompanying illustrations), the third tank discharging into the mud pit.

At Singu on the river bank where topography does not permit use of these tanks an ordinary mud ditch is used. One mud screen is used at Masimpur and there is one at the mud plant in Yenangyaung originally built for an earlier deep test, now abandoned. This mud plant is connected with Well No. 2821 by pipe line and mud is occasionally sent there for cleaning and reclamation of weight material.

The pumps at a central mud-treating plant

The circulation rates of the electric pumps are also low, 160 Imperial gal. per minute being a normal rate. The sand drilled is rather fine and the particles mix with the mud to such an extent that the quantity of sand that could be removed by screening would be small.

Testing

Burmese chemists make the field tests. The routine tests made hourly

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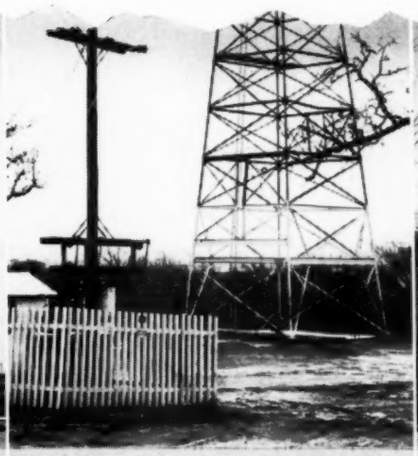
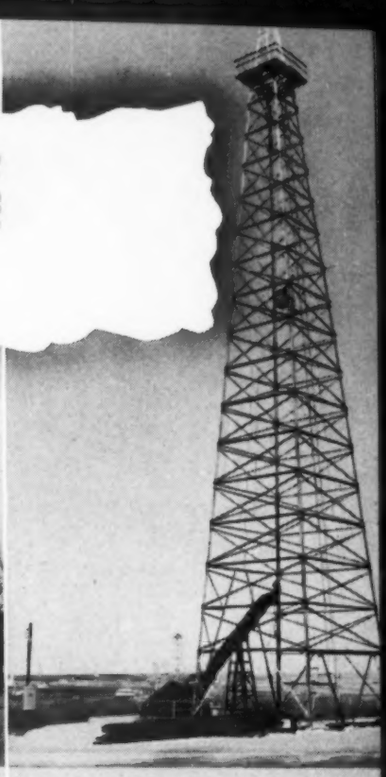


St. Louis, Okla. Producing 2460 bbls. fluid per day from 4161'.

Approximately 3% oil is being economically produced from this Elbing, Kansas, well.



Typical Western Kansas Well. Allowable of 54 bbls. per day produced by Reda in 2¾ hours daily.

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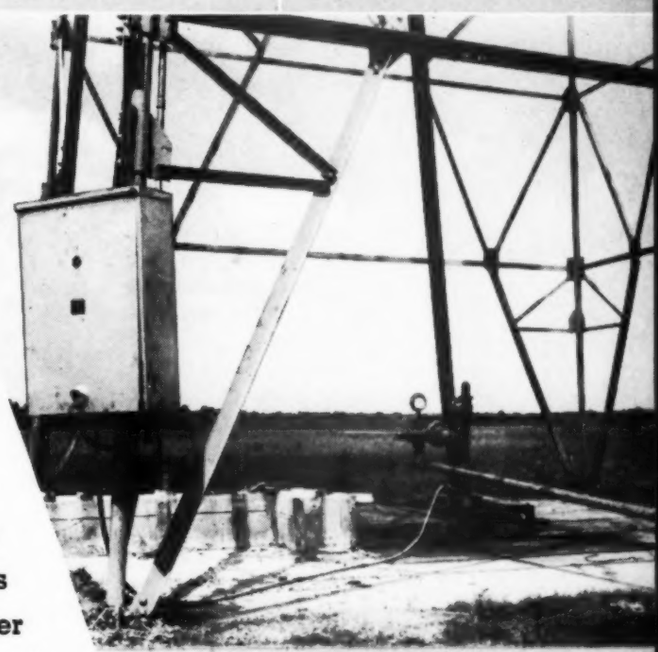
The cost figures gathered to prove this point have come from all over the Mid-Continent area where the acceptance of Reda as the lowest cost method of pumping oil wells was again proved in 1937. In that year Reda Pumps produced 2% of the total gross crude oil production of the United States. With lower first cost and lower lifting cost, Reda is the logical equipment for your pumping wells. Give us the opportunity to prove it.



A 15 H.P. Reda unit is used in this well. Set at 2720'. Esperson Field, Texas.

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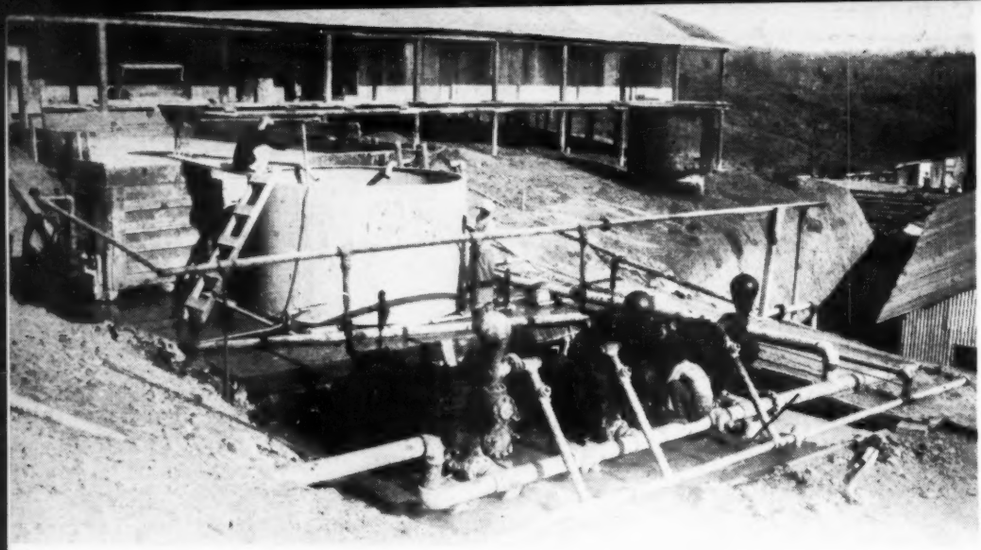

Mud-mixing equipment for a deep test

at the well in which pressure-drilling is being used, are (a) viscosity by Digboi instrument, (b) weight, (c) sand content by screening, drying, and weighing, and (d) chloride salinity of mud. At the ordinary wells in Yenangvaung, a "mudwate" indicator is used. When the viscosity exceeds 200 D. U. the mud is treated to reduce it to 50 or 60 D. U. if possible, a small batch being treated in the laboratory first to determine the amount of reagents needed.

In the research laboratory at Khodaung (Yenangyaung field) the effect of high pressures on viscosity is being investigated. Little work has yet been done on determination of the wall-building characteristics of any muds, but, their importance being known, present plans include the making of tests in a filter press.

In the field laboratory at Singu two-hour settling tests are being made in a 100-ml. glass cylinder. The customary weight apparatus is a cup containing 62.3 ml., which is weighed on a pan balance, the weights giving the density in lb. per cu. ft. directly. There are many forms of the Digboi paddle viscosimeter, which is used to measure the viscosity in Digboi units.

Chemical Treatment

Chemical treatment is being used extensively. The three chemicals being used at present are: (1) sodium silicate (water glass), (2) Cutch, a local tannin extract prepared in Burma from the *Acacia catechu*, and (3) soda ash.

Cutch is a semi-solid brown substance, which is marketed in grass baskets containing about 30 lb. each, and is quite impure, containing leaves and trash. Sixty to 75 lb. is placed in a drum with 50 gal. of water, heated by a steam jet, and the leaves removed by straining. This solution is then used alone or mixed with the soda ash or water glass. At Well No. 2821 the heavy mud was treated on alternate days, cutch and sodium silicate usually being used to reduce the viscosity from 250 D. U. to 50 or 60 D. U.

The Singu shale is said to be particularly susceptible to brine or cement, addition of five percent by volume of cement making the mud semi-solid. Water glass has proved ineffective in breaking this viscosity so the mud is treated with cutch and soda ash; that is to say, in effect, with sodium tannate. After cement is drilled, sometimes as much as one percent by volume of soda ash is used. Soda ash and sodium silicate are both imported. Treatment to reduce the gelling action of the Singu shale has aroused considerable interest, because after shutdowns excessive pump pressure is required to restore circulation.

Mud Reclamation

Mud screens are uncommon; settling is the only means generally available for removing cuttings. Weight material in the mud from Well No. 2821 is recovered by washing at the "central plant," which was built for the first deep test, and by repeated settling. A big steel cone classifier was built some time ago, but apparently it was unsuccessful, as it has been discarded. The company is somewhat interested in centrifugal separation but has not yet obtained approval for purchase of a separator.

Looking down on the mud pits built for a deep test. Beyond the well to the right is a de-gassing tower, used for removing the gas from the circulating fluid by letting it cascade downward from the top after coming from the well

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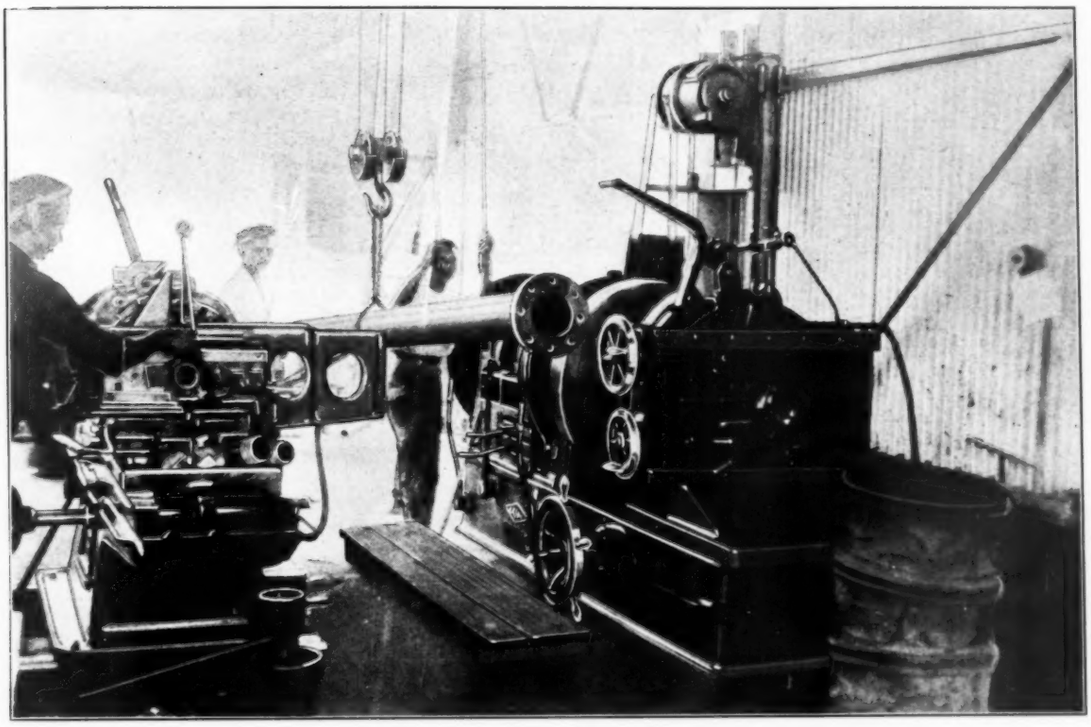

Landis Pipe Machines in a refinery pipe shop at Tjepoe, Java, D.E.I.

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Above—A well drilling on a tide-water location in Seria field

Numerous Wells Are Being Drilled in the Island of Borneo

Known fields are being developed, deeper strata tested, and promising structures explored

By JOHN F. DODGE and WALLACE A. SAWDON

THE island of Borneo, comprising Sarawak, Brunei, and British North Borneo under British control and Borneo held by the Netherlands, is the third largest island on the globe. All oil is produced from fields situated on or near the coasts. There are three general areas of production: that around Miri and the new Seria field on the northwest coast; Tarakan Island toward the north end on the east coast, and the widespread area toward the south end of the east coast.

Production from the Netherlands operations on the east coast has far exceeded that from the British on the northwest coast, but production from the former area is showing a decline, whereas that of the latter has been increasing. Production data for the combined Sarawak and Brunei fields and for the combined fields on the east coast of Borneo are given in Table 1[1].

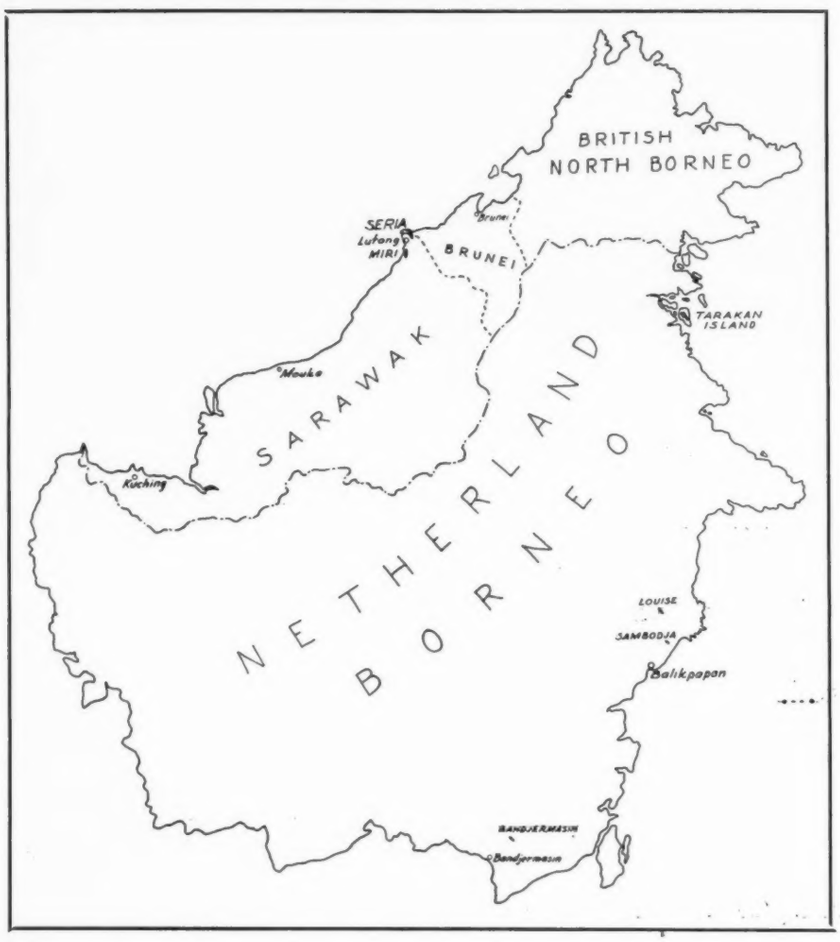
The general geology of the east coast of Borneo is indicated in Table 2. The correlation of this district with northern and southern Sumatra and with Java is given in the generalized cross-section accompanying the introductory article on the "Oilfields of India, Burma, and the East Indies."

Miri Field

The Miri field lies on the coast of Sarawak near the Brunei boundary. Ships anchor about three miles off shore. Passengers and materials are transferred from shipboard to company launches and thus carried to shore. Miri is the headquarters for Sarawak Oilfields, Ltd., and is the site of extensive offices, warehouses, shops, and hospital.

The oil in the Miri district occurs in sand lenses. The old Miri field itself is approximately four miles long and one and one-half miles wide. The 586 wells completed in this area were drilled by cable tools. A production of 700 bbl. of 28- to 45-deg. A. P. I. paraffin-base oil is now being taken from fewer than 400 of these wells.

[1]From A.I.M.E. "Petroleum Development and Technology, 1938."



Map showing location of fields in Borneo

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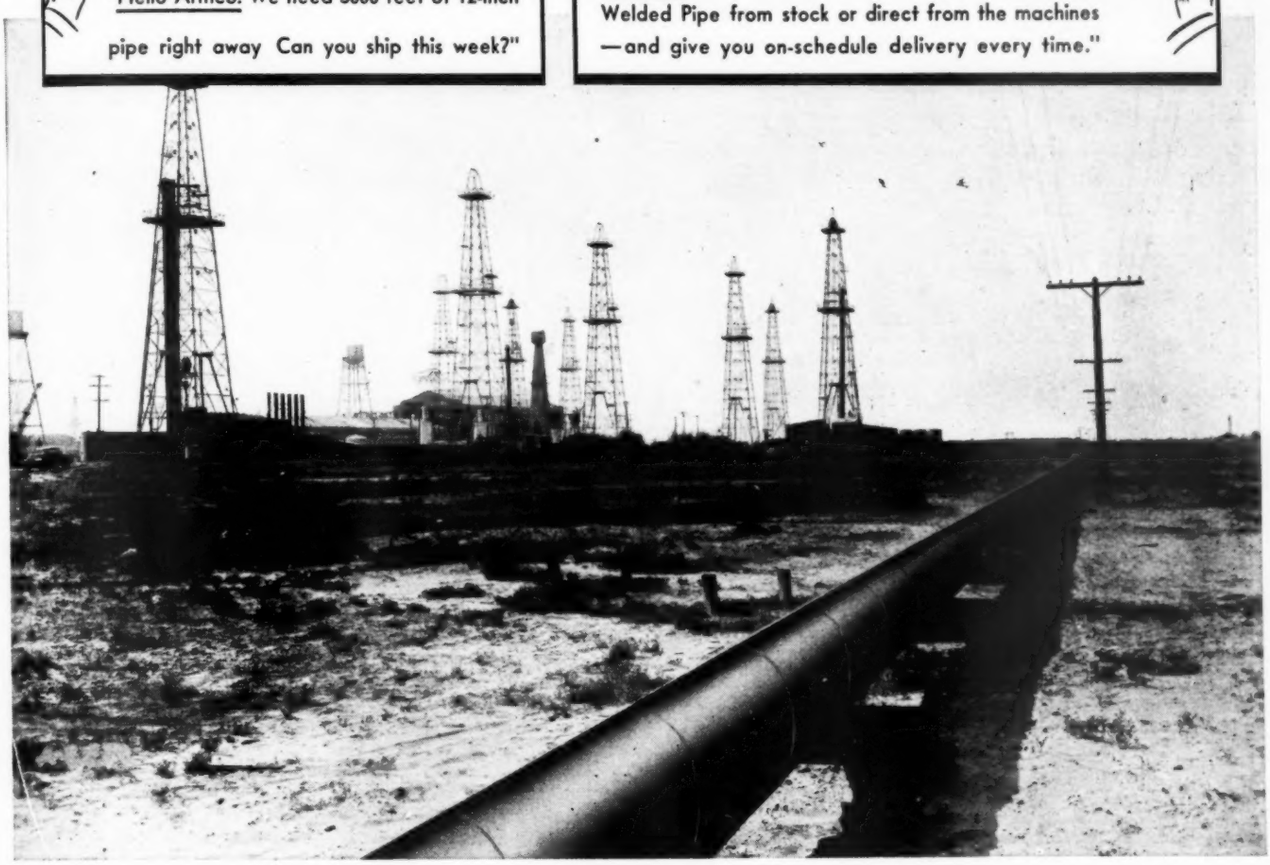

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TABLE 1

	Sarawak and Brunei	*Balikpapan and Tarakan*
Age in years to end of 1937	28	42
Total bbl. oil to end of 1937	78,542,825	343,586,660
Total bbl. oil during 1936	4,861,000	12,546,000
Total bbl. oil during 1937	5,733,000	12,309,000
Average daily, December, 1937	16,380	33,774
Average daily, per well, December, 1937	36	47
Total gas, million cu. ft., 1936	3,012	9,984
Total gas, million cu. ft., 1937	3,423	10,903
Wells completed to end of 1937	566	1,361 (Est.)
Completed during 1937	25	47
Abandoned during 1937	1	12
Temporarily shut down at end of 1937	15	-----
Producing oil only at end of 1937	452	715
Producing gas only at end of 1937	2	2
Total pr.ducing at end of 1937	469	717
Average depth in ft.	340–5,280	230–2,620
Average depth to top of producing zone	130–5,242	210–2,600
Flowing wells at end of 1937	13	29
Pumping wells at end of 1937	403	670
Gas-lift wells at end of 1937	36	16

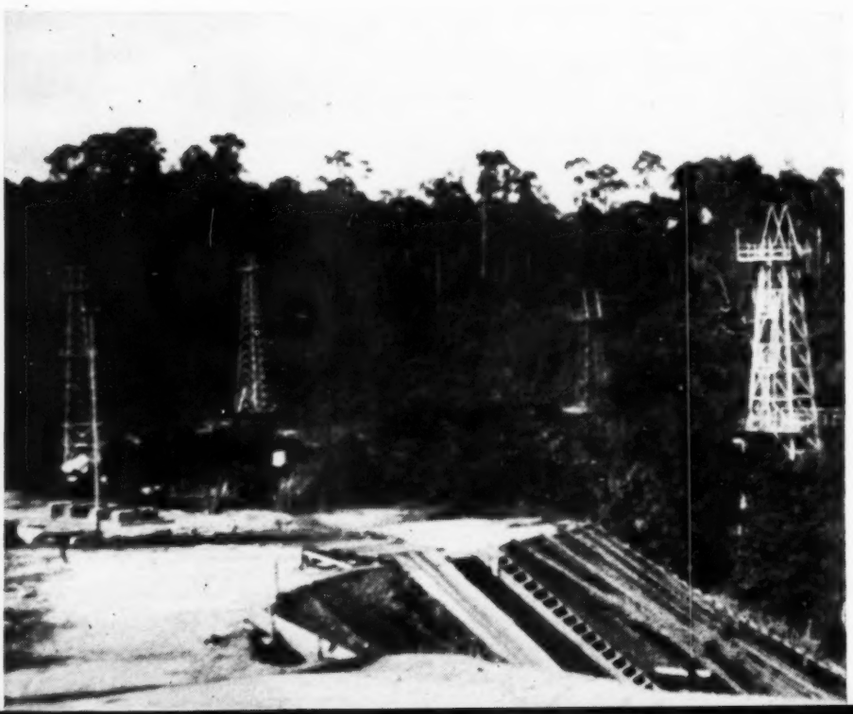
TABLE 2
Stratigraphic Column—East Coast Borneo

Period	*Formation*	*General Description*
Pliocene	Kembang	Gray and red sandy clays, ferruginous sandstones, lignite, and resin; coal from Kembang and Balikpapan. Oil from Balikpapan. Production at Tarakan. Thickness 2000-3000 ft.
Miocene	Moeara Djawa	Soft gray clays and sandstones. *Myogypsina polymorpha* and *Lepidocyclina.* Coal from Moeara Djawa. Oil from Moeara Djawa. Thickness 2000-3000 ft.
	Sanga	Sandy and shaly clays.
	Sanga	Clays, plant deposits, and slatey limestone. *Myogypsina thecideaformis* and *Lepidocyclina.* Coal from Sanga Sanga. Oil from Sanga Sanga. Thickness 4000-4500 ft.
Oligocene	Prangat	Limestone, clayey shales. Nodular clays. Coal from Prangat. Some gas.

(From "Petroleum in Dutch East Indies," by Fred B. Ely, A.I.M.E. Petroleum Development and Technology, 1931)

This oil is piped to the company's refinery at Lutong for processing. The depths range from 600 to 2000 feet. About ten bbl. of water is produced with each bbl. of oil and the oil and water are regarded as coming from the same zone.

One cable-tool rig is working daylight hours only in a 600-ft. pool and is obtaining sufficient production to offset the rapid natural decline. Drilling is easy and mostly old equipment is being used. The deepest well in this district was drilled to a depth of 5000 ft. but no showings were encountered at the greater depths. A test to 10,000 ft. is now contemplated but no definite plans have been made for drilling.



The derricks of the Djoesata field on Tarakan Island can be seen rising above trees of the forest

Seria Field

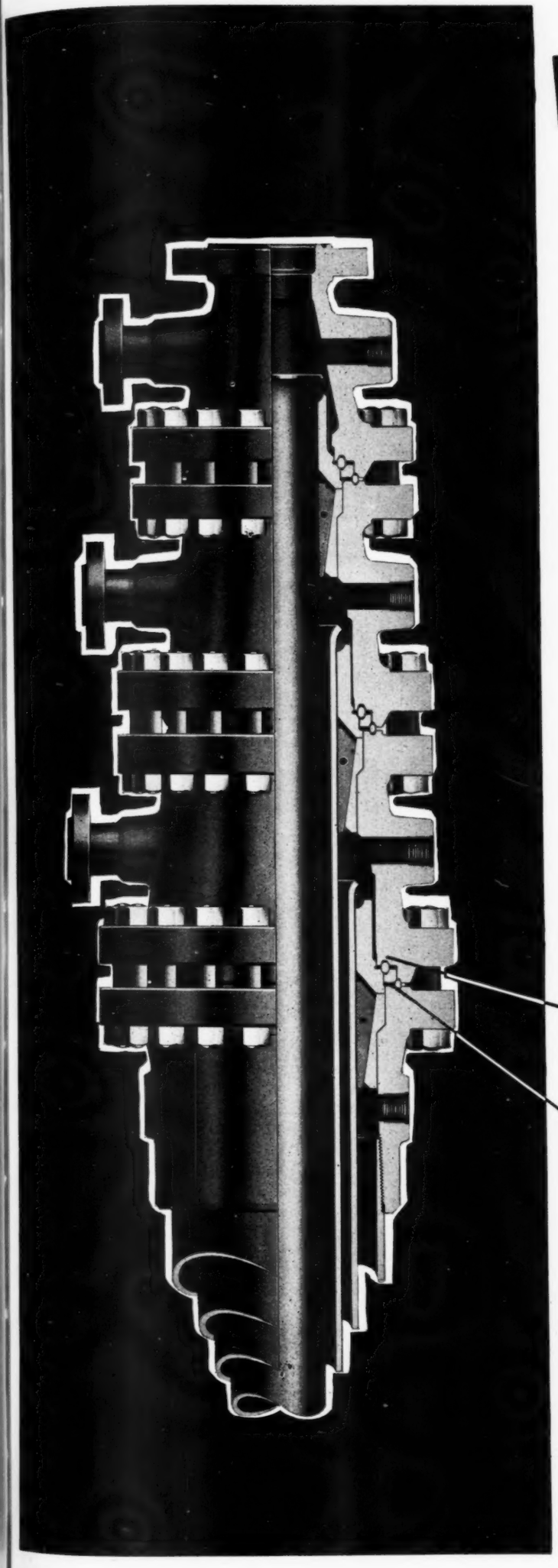
The Seria structure lying along the boundary between Sarawak and Brunei is situated 30 miles northeast of Miri and is reached by a road that crosses three rivers and is partly in the jungle and partly along the sea shore. The structure lies nearly parallel to the coast and is six miles long and one mile wide. One end extends into the sea and although its limits have not been defined the structure apparently continues seaward a mile or more.

Operating headquarters of the Seria field are at Kuala Belait, the mouth of the Belait River, 22 miles from Miri. Here the British Malayan Petroleum Company, Ltd., has extensive shops, warehouses, yards, and offices. This company is subsidiary to the Sarawak Oilfields, Ltd., which conducts the operation of the Seria field. The formations are shale, hard sandy shale, and bands of hard sandstone. Drilling conditions are exceptionally good and operations are facilitated by a well-maintained mud-conditioning system. Intermediate water and gas zones, however, present problems, and cementing operations require high pressure.

The thickness of the producing zones varies from 80 to 400 feet. The thickness of the productive portion of the Seria zone, recently discovered at a depth of 6000 ft., is not known, but a thickness of 400 ft. has been penetrated.

The usual casing program consists of a 13⅜-in. surface string set at depths of 200 to 1000 ft., an 8⅝-in. water string, and 6⅝-in. liner. Standard practice is to use whirler float shoes on casing and in deep wells a float collar also. The wall of the hole is scraped before liner is run.

The liner is made-up to contain blank sections opposite the intermediate water and high-pressure gas zones. Cement retainers are used as casing bridge plugs for cementing the blank sections of pipe. Operators contemplate cementing the blank liner solid



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(1) Permits running, landing, cementing and suspension of casing strings through blowout preventer hook-up.

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(2) FLEX-STEEL GASKETS hold down casing hanger assembly rigidly.

(3) Split Slip Bowl and Split Slip assemblies easily engaged around casing string on derrick floor and passed through blowout preventer hook-ups. Auxiliary Welding Hanger, installed after casing has been suspended, prevents casing string from settling in slips and swaging due to sustained tension, vibration or other cause.

(4) Slip suspension permits landing casing at any point in the hole, without releasing tension in string, or setting weight of string on bottom while cutting nipple, etc.

(5) 45° beveled seat in casing head serves as support for slip-bowl only — no seal being effected at this point. Mis-alignment or "cocking" of slip bowl, due to bit scars on tapered seat in head, are compensated by mis-aligning feature of FLEX-STEEL GASKET ASSEMBLY.

(6) All sealing is on polished steel surfaces applied at the moment of completing casing suspension operation. *No surfaces relied upon for a seal are ever exposed to damage.*

(7) All-flanged construction eliminates casing-size threads above surface pipe.

(8) Available with solid slip bowl having seal ring which seals annular space the instant pipe is suspended on the slips.

(9) All sizes are full-opening.

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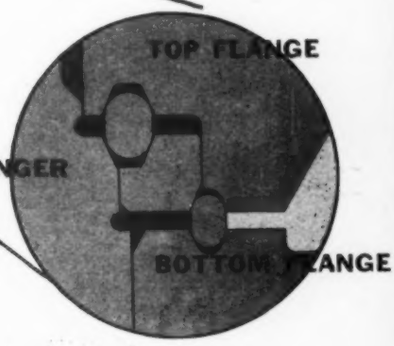

Close-up view of Cameron FLEX-STEEL MULTI-RING GASKET ASSEMBLY, the unique design of which provides an all-steel sealing and hold-down means, as well as a mis-aligning feature which compensates for any wear on 45 degree beveled seat in Casing Head.

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In the foreground can be seen paraffin wax sacked ready for shipment to China. Wax is an important export and goes from the Balikpapan refinery to all parts of the world

and then gun-perforating opposite the producing strata. If water or gas zones are perforated, high-pressure cementing through a cement retainer can be used to effect a shut-off.

The 100th well was recently spudded in the Seria field. At present approximately 90 wells are producing 15,000 bbl. per day, all flowing or on gas lift. The oil is similar to that at Miri and is transported by pipe line to the Sarawak Oilfields, Ltd., refinery at Lutong. The producing zones extend from a depth of 1800 to 6000 ft., the best wells being completed in the deeper sands. There are several oil-producing zones, and there are high-pressure gas zones and water strata between.

A directionally-drilled well recently completed had an initial production of 2000 bbl. per day and casing pressure of 1700 lb. per sq. inch. The bottom was approximately 900 ft. beyond the shore. Other directionally-drilled wells are now planned to explore the structure to seaward. The equipment used consists of survey instruments, knuckle joints, and whipstocks.

Five rotary rigs are in active service but only two drilling crews are normally employed. The crews are switched from one well to another when there is a shut-down. The most recently acquired equipment consists of a heavy unitized rotary outfit complete with heavy hook, elevators, tongs, crown and travelling blocks, and 7½-in. by 14-in by 14-in. pumps. Steam is used for power and, because of the higher cementing pressures contemplated, the operators plan to use higher pressure boilers. The present steam plants are inadequate for large cement jobs, and high-pressure pumps also will be required.

Test Wells

Sarawak Oilfields, Ltd., is planning the drilling of a well on the coast 12 miles from Brunei as a deep test for that area.

The company's Mateding Test near Mukah, also on the coast half way between Miri and Kuching, has been drilled to a depth of 5000 feet. Four oil zones have been penetrated but the well is still in the exploratory stage. It is expected that intermediate water strata will present a difficult problem in that area. On all wildcat tests, water strings are 9⅝-in. instead of the 8⅝-in. used in proved areas.

Lutong

Lutong is seven miles northeast of Miri and lies on the north shore of Miri River. The Sarawak Oilfields, Ltd, refiinery, in which all oil from S.O.L. properties is refined, is situated here. The present capacity of this refinery is 20,000 bbl. per day but facilities are to be increased.

Sea lines extend three miles from shore at Lutong to provide for the loading of tankers. A new 10-in. sea line is to be laid next year.

Balikpapan Administration

Although the headquarters of Bataafsche Petroleum Maatschappii are at Balikpapan, there is no production in the immediate vicinity. Here, however, are the offices, shops, warehouses, and all auxiliary equipment of a well-planned community devoted to oil and army operations. Ships and tankers from all parts of the world touch this port. Activity has probably been greatly increased by the present tension in the Far East.

The Borneo oil is a heavy crude of large wax content. Diesel and fuel oils from this crude meet with general favor. Production from the Balikpapan Administration is approximately 20,000 bbl. per day but is declining.

Six rotary rigs are active in the surrounding fields. There are also two small rigs, operated entirely by Bornean workmen, drilling shallow wells and one rotary machine being used for core drilling.

Production depths range from 1500 to 3000 ft. but deeper drilling is under way in various areas and is scheduled for others. A company amphibian plane is being employed for mapping and considerable attention is being given to exploration in numerous areas of the eastern and southern parts of the island. Limestone outcrops in the steeply rising hills where the B.P.M. buildings are situated suggest that an oil reservoir may underlie the company's headquarters. Coring in this entire area will soon determine the possibilities.

Louise is the most important field in this administration at the present time. Sambodja is next in importance, and Bandjermasin to the south, which is still a small area, is looked upon with favor for further development.

Tarakan

This Administration comprises Tarakan Island, which is approximately 16 miles in length by nine miles in width. Here the B.P.M. produces 14,000 bbl. per day from 500 wells. The crude is a heavy fuel oil as it comes from the wells. The producing depths range from 500 to 2600 ft. and there are as many as six producing zones in some wells, their thickness varying from 15 to 60 feet. The oil is moved to the wells by water drive, and all the wells are being pumped. Sand and corrosion are troublesome.

At the present time there are five rotary rigs drilling. One is being used on a deep test at Djoesata, which, when coring ahead at 600 ft., was reported as having some showings. The topography of Tarakan Island is generally rough and broken, and the topography and previous findings indicate that there are excellent chances of finding deep production in several areas on the island. A 10,000-ft. test is scheduled to be started this year at Pamoesian, the main field of Tarakan Island, and a general program of drilling more shallow wells is now under way.

How to get the MOST in Pumping Service at the LOWEST Cost per Barrel

Use FLUID PACKED PUMPS In Sandy Wells

Fluid Packed Positive Pull Type

Fluid Packed "Marginal" Type

You can't fight sand. Close-fitted pumps can't stand up in service where sand conditions prevail. Pumps fill up, plungers freeze, close-fitted parts are soon scored and worn beyond the point of usefulness or hope of repair. Frequent pulling jobs, down-time and maintenance expense eat heavily into profits.

Years of economical service in sandy wells have proved the value of the Fluid Packed principle to operators all over the world. Two concentric traveling tubes, connected together at their upper ends, reciprocate over a stationary standing tube loosely fitted between them. The long annular channels between the tubes become filled with the fluid being pumped—the "fluid packing" that never wears out—and the liberal clearance provided allows even large quantities of sand to be carried with minimum wear or abrasion. The loose fit between the tubes reduces friction, avoids freezing, and lessens the hazard of rod breakage by permitting the plunger to conform quickly to rod movement. These factors greatly increase pump life, reduce down-time and pulling jobs, and insure uniformly efficient pumping service.

The same qualities that make Fluid Packed Pumps efficient and economical in sandy wells insure exceptional service from them under many other conditions also. Give them a trial —there is a size and type to meet your needs.

Use FLUPACO Groove Seal PUMPS In Ordinary Wells

Flupaco Groove Seal Pumps depend on uniform close fit between the plunger sleeves and the barrel tube throughout the ***entire length of the stroke*** to establish and maintain their reputation for long, efficient service life and economy. The plunger sleeves are ground to extreme accuracy and operate in specially fabricated cold-drawn seamless steel tubes selected for hardness, roundness, precision, and ***uniformity of dimension*** from end to end.

Flupaco plunger sleeves are made of specially processed and heat treated chrome-molybdenum iron with the physical properties that insure high resistance to wear and abrasion. They are available in two standard, uniform grades: "Supreme," harder and especially suitable for severe conditions, and "Service," lower in price —the best buy for general use.

Flupaco Petrol A

Among the three pumps in the Flupaco Groove Seal group you will find the one to meet your needs. The "Volume Producer" is made in long lengths for service in deep, large volume wells; the "Producer" is used in wells of medium depth and volume. And the little Petrol A, exceptionally low priced but a precision pump all the way through, is specially designed for use in stripper wells where both initial expense and operating costs must be held at the minimum.

Install one or more of these Flupaco Groove Seal Pumps. Give them a real test, keep a close record of costs and performance. You'll find that the quality built into them pays dividends in lower lifting costs over a longer period, with reduced down-time and repair.

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Prolific Production Expected in Saudi Arabia and Kuwait

Although drilling has scarcely passed the exploratory stage, prospects of large yields are excellent

By RALPH H. KING

AN extensive area on the northeastern side of the Arabian Peninsula, which has been prospected only in the last few years, gives promise of rivaling the Iran-Iraq geosyncline, both in number, size, and productivity of fields and in scientific control of reservoirs. As in Iran and Iraq, large areas are controlled by individual companies, so that, although these companies may be owned by two or more other companies, operation of all productive areas as completely unitized projects on a sound scientific basis is virtually assured.

Saudi Arabia

The Sultanate of Saudi Arabia occupies the eastern part of the Arabian Peninsula and is bounded on the east by the Gulf of Iran. Nevertheless the country is largely desert. Topographically, the country is a plain, sloping gradually from the interior to the coast. Sand covers much of the surface, concealing the sedimentary strata. Geological study is therefore locally somewhat hindered and much of the prospecting is necessarily geophysical. Aerial photography is used extensively in mapping and exploring.

As in Iran, Iraq, and Bahrein Island, the structures expected to yield oil are the anticlinal folds and domes in the Tertiary and Cretaceous strata. Several such structures have been mapped but not yet tested, but on the basis of geologic structure alone the fields of Saudi Arabia appear to compare favorably with those of the nearby countries.

The California Arabian Standard Oil Company, a subsidiary of the Standard Oil Company of California, holds a concession covering the entire coast and the area extending into the interior for a distance of approximately 150 miles. No definite boundary has been established, as the preliminary exploratory work has not as yet reached more than a few miles inland. The size of the concession is almost equal to that of the State of California, so naturally complete exploration would require several years.

The first structure to be tested by actual drilling was the Damman dome. (Map, p. 91.) The first well drilled was a small well but nine more wells were drilled, all of which yielded some oil, although the quantity produced did not warrant the construction of a pipe line or refinery. Well No. 2 produced 3840 bbl. of 50-deg. gravity oil at a depth of 2175 feet. The depth of the wells is 2000 to 3000 ft., depending upon structural position.

The discovery of more prolific producing strata in Bahrein when old wells were deepened encouraged the operators at the Damman field to deepen their wells, and as in Bahrein, a much greater production was obtained. Other wells are now being deepened. This deeper, more productive zone lies at a depth of approximately 4700 feet.

In drilling the wells a steel derrick was used, set on concrete piers, and a combination rig was installed, although most of the drilling was done by rotary tools.

A test well has been drilled on the El Alat structure, also. This area is about 25 miles northwest of the Damman field. The exploratory well tested the shallow zones and obtained several tar showings but no production, so was abandoned, but will probably be deepened to test the productive zone found at a depth of 4700 ft. in the Damman field.

Kuwait

The Sultanate of Kuwait is virtually a desert at the head of the Gulf of Iran. It has been a protectorate of Great Britain since the war.

In 1934 the Kuwait Oil Company, Ltd., owned equally by the Anglo-Iranian Oil Company and Gulf Oil Corporation, was granted a concession covering the entire country. Two shallow core holes had been drilled in 1931-32 by the Anglo-Iranian Oil Company.

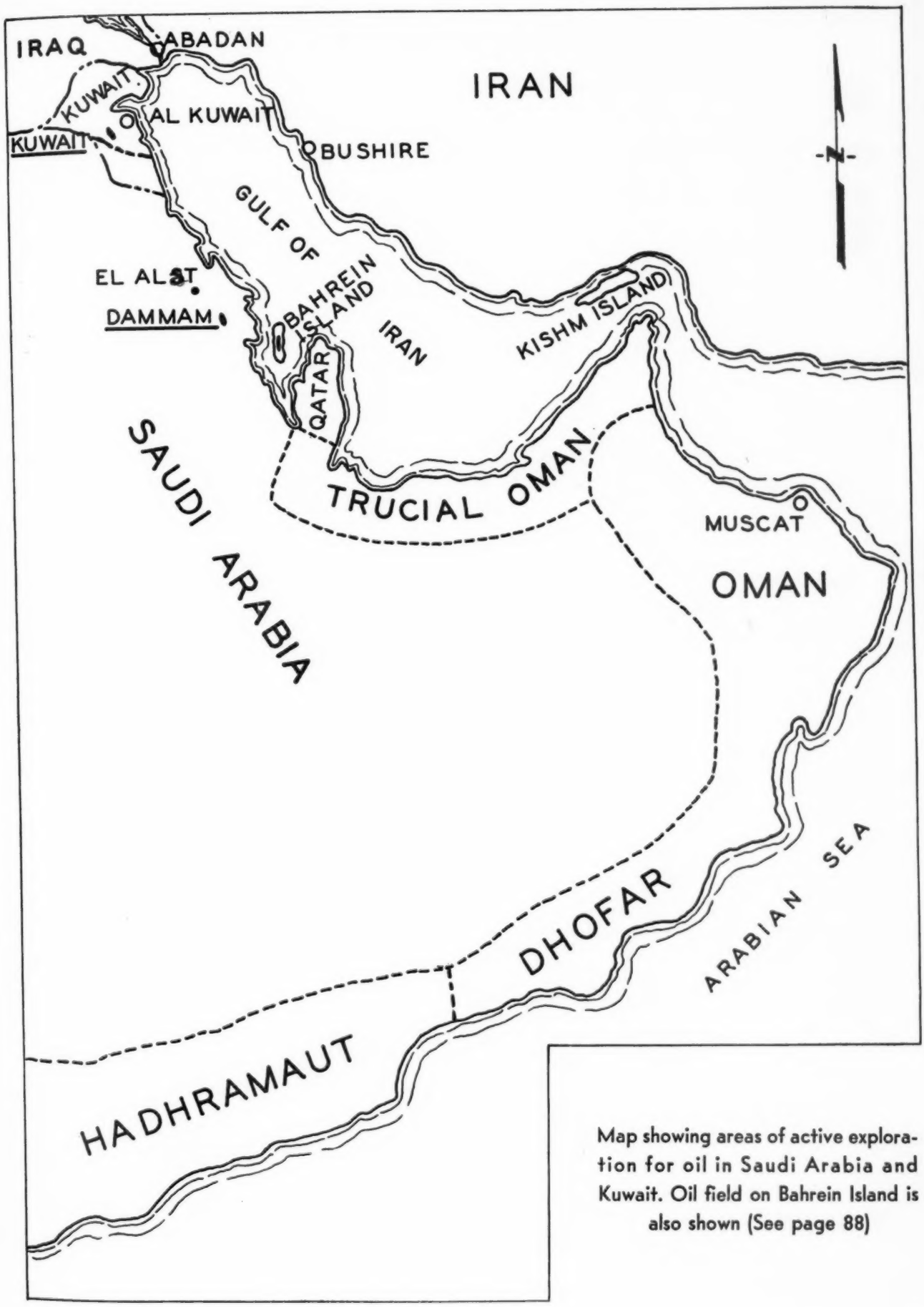
One of these core-drilled wells was sunk near the Bahrah seepage on the north side of Kuwait Bay nearly due north of Al Kuwait. The other was drilled near Burgan Hills, about 30 miles south of Al Kuwait. Neither well penetrated beyond the Miocene so results were inconclusive.

The first test well drilled by the Kuwait Oil Company was drilled at Bahrah, near the first-mentioned core hole. A combination rig driven by gasoline engines was used because of the scarcity of water. The actual drilling was begun in 1936 and the well was abandoned at a depth of 7950 ft., no promising showings having been found.

After geophysical surveys of the entire country, the site for a second test well was selected. As before, it was near an old Anglo-Iranian core hole, this time the one near Burgan Hills south of Al Kuwait.

This well was drilled by rotary rig and was begun in October, 1937. Circulation was lost repeatedly in the extremely porous Eocene and Cretaceous limestones, but at a depth of 3400 ft. shaly strata were encountered and drilling was easier. At a depth of 3670 ft. oil and gas under high pressure were obtained from a sand and it was necessary to add weight material to the drilling fluid in order to complete the well. Casing was cemented above this productive stratum.

Although the field has not been outlined it appears that the wells will be prolific and the structure is large. The probability is that a major field will be developed. The field is about 200 miles north of El Alat in Saudi Arabia.



Map showing areas of active exploration for oil in Saudi Arabia and Kuwait. Oil field on Bahrein Island is also shown (See page 88)

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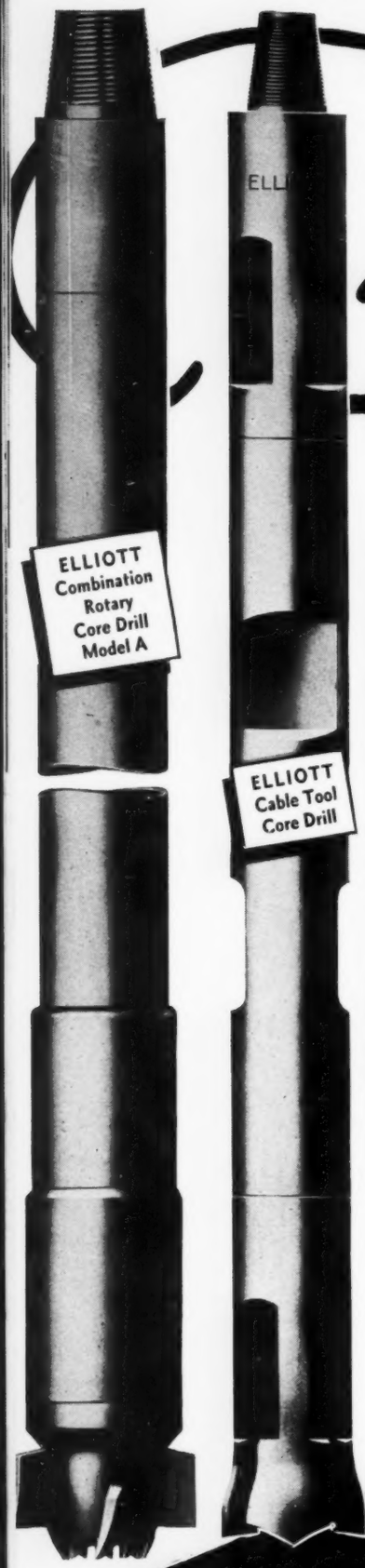

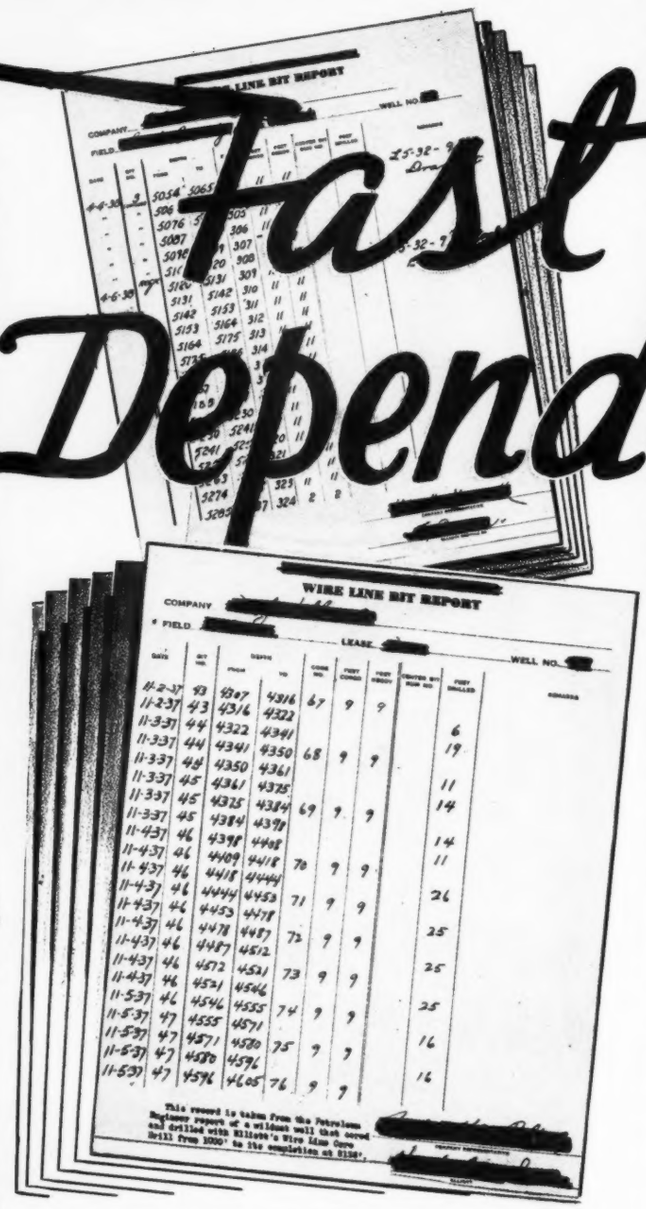

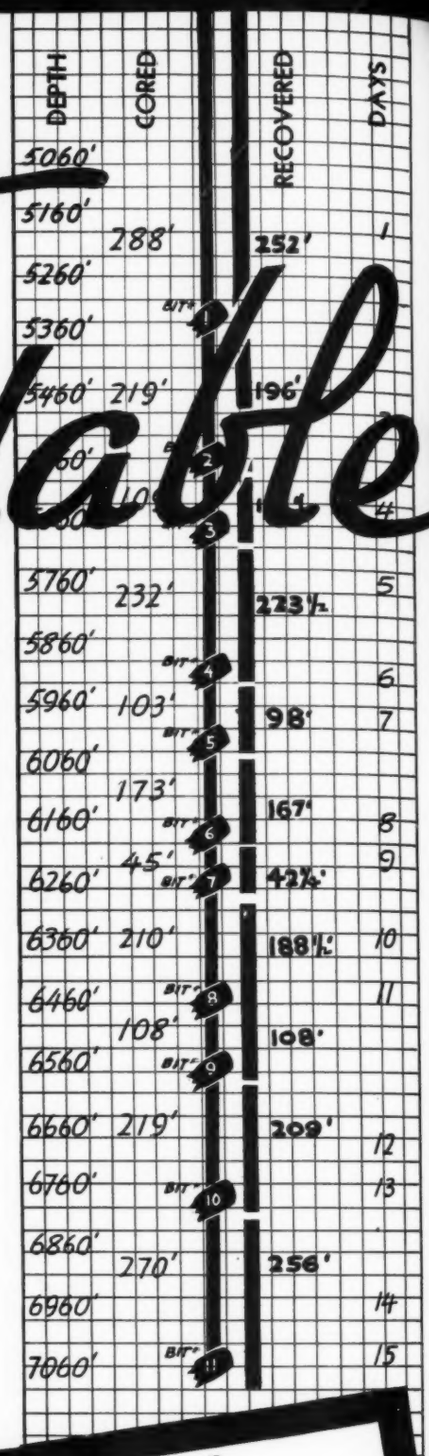

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LOG

Footage Cored	1,976 Ft.
Core Recovered	1,884¾ Ft.
Number of Days	15
Number Cutter Heads	11

Formation: Alternating firm shale, sandy shale, and streaks of sand.

*ELLIOTT always has been essentially a CORE DRILLING organization, and is the only manufacturer designing and manufacturing core drills for its own use in conducting a coring service to oil companies on a highly competitive basis. This wealth of actual coring experience covering nearly twenty years has enabled Elliott to develop coring equipment that is unequalled in safety, dependability, and high core recovery

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Three types of Elliott Core Drills cover the entire range of rotary and cable tool drilling procedure, with interchangeable cutter heads designed for all formations from the hardest to the softest; assuring minimum investment in coring equipment for either method.

ELLIOTT WIRE LINE RETRACTABLE CORE DRILL and DRILLING ASSEMBLY Assures faster coring with fewer round trips of the drill pipe, and high recoveries in all formations. Can be converted from a core drill to a drilling bit by replacing the inner barrel assembly with the drilling assembly (both illustrated) For detailed information mention Catalog No. 37-W.

ELLIOTT Model A COMBINATION ROTARY CORE DRILL: A scientifically designed tool, engineered to meet actual conditions in the hole, which embodies that high degree of simplicity so essential to safe, dependable performance thousands of feet under ground. Makes fast hole and high core recoveries in all formations. Catalog No. 36-R.

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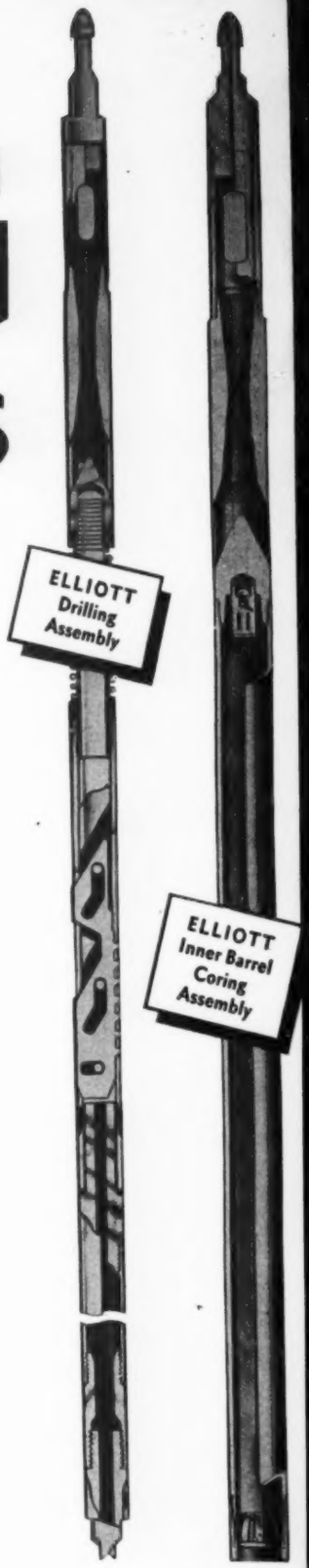


The Elliott Wire Line Core Drill is converted into a drilling bit merely by replacing the inner barrel assembly with the drilling assembly.

Bahrein Petroleum Company's main camp industrial section

Difficult Drilling Conditions Mark Development of Bahrein Field

Cavernous limestones, extremely steep temperature gradient, flows of hot salt water, abnormally high pressure, and tar pockets complicate drilling of wells

By K. C. SCLATER

IN the Gulf of Iran, just off the coast of Saudi Arabia, lies the small island of Bahrein, 12 miles wide and 27 miles long, which boasts one of the most important producing oil fields in the Eastern Hemisphere. The field is situated almost in the center of the island on an elevation that rises 450 ft. above the surrounding terrain, which has a visible rim rock of limestone that virtually outlines the general limits of the field. Although discovered only six years ago, this field has already acquired a remarkable development history. The first well, brought-in in June, 1932, had an initial rate of production of 100 bbl. an hour from a depth of 2008 feet. Since then a conservative, thoroughly engineered program of exploration and development has been followed and some 50 wells drilled, all but two of which are commercially productive and produce by natural flow. The field is being developed as a unit, being controlled and operated by the Bahrein Petroleum Company, Ltd., owned jointly by the Standard Oil Company of California and The Texas Corporation. During 1932 only 902 bbl. of oil was produced, but last year, 1937, the total production from this field was 7,762,264 bbl., and on January 1, 1938, the total cumulative production was 13,989,057 barrels.

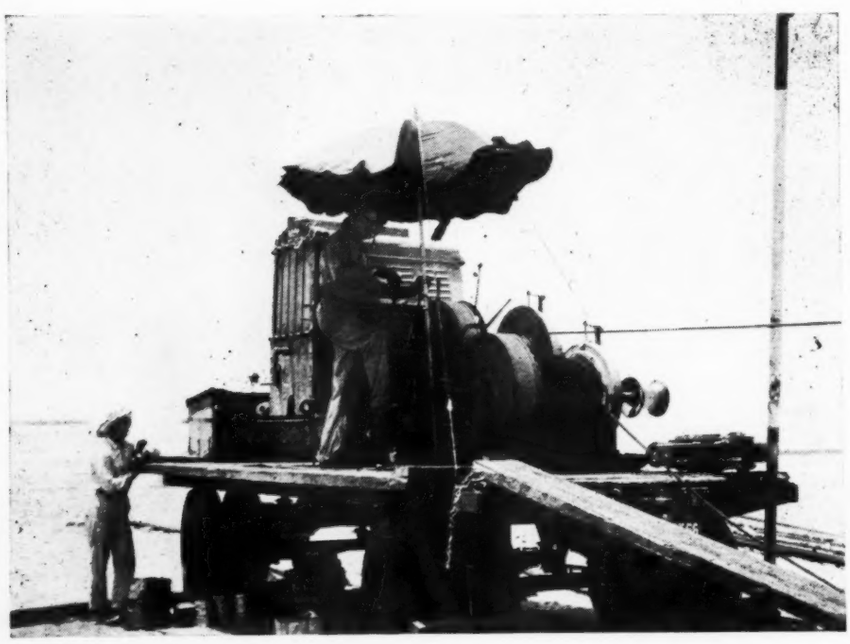
Soon after the first well was drilled a second well was completed. It had an initial daily production of 1500 bbl. from about the same depth as the first well. Both wells were drilled with cable tools. Later a combination rig was put into service for deeper drilling and many tests were made in all directions and quite distant from the original location. During the first two years six wells were drilled, the producing characteristics of which indicated positively that the field was extensive and capable of sustained production.

During 1934, eight wells were completed at depths ranging from 2058 to 2253 ft., and showed initial productions ranging from 1500 to 5000 bbl.; one well of this group was estimated as being capable of flowing as much as 11,000 bbl. per day.[1]

By the end of 1935, 20 wells had been completed in the Second (Main) Pay. During 1936, 19 more wells had been completed in the Main Pay. The present system of spacing wells places them 3000 ft. apart in a rhombic grid, or one well to approximately 180 acres.[2]

Two non-productive wells were drilled to test the Third Pay at a depth of about 2900 feet. By the end of 1937, 45 wells had been completed as producers in the Second Pay.

Wells in the Main Pay now have an



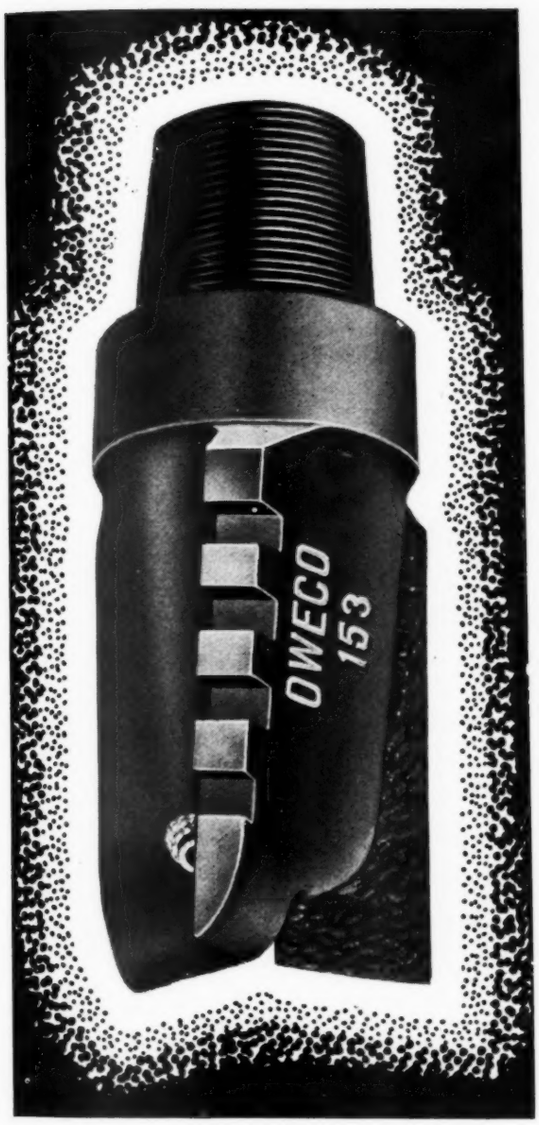
Bailing-out cement prior to gun-perforating

[1] "Petroleum Development in Arabia for the Year 1934," p. 481, A.I.M.E., Petroleum Development and Technology, 1935.

[2] "Petroleum Development in Bahrein Island and Saudi Arabia During 1936," p. 562, A.I.M.E., Petroleum Development and Technology, 1937.

Straight Talk

ABOUT THE WORLD'S STRAIGHTEST DIGGIN' BIT



PATENT PENDING

Showing sharpened tooth arrangement of offset blade which does the work.

"OWECO"

Here is the bit that has been making hole history for the past half year. Hundreds of runs in Texas and Louisiana Gulf Coast wells have proven its effectiveness in *straightening crooked holes* and in *drilling straight holes fas.er.* Ask the men who use them.

The "OWECO" Bit is built eccentric, resulting in two blades extending radially only a short distance from the body and one blade extending considerably more. This offset blade is notched along its reaming edge. As shown in the accompanying sketch, the drill collar is permitted to lay close to the low side of the hole. As the drill collar rotates about its axis the offset blade is brought in contact with the low side of the hole where the sharp teeth underream the formation. This constant underreaming of the lowside while drilling is in progress gradually brings the hole back vertical. Once vertical, with "OWECO" on bottom, any slight deviation caused by shells, breaks, etc., is automatically corrected while drilling. Fully descriptive literature available upon request.

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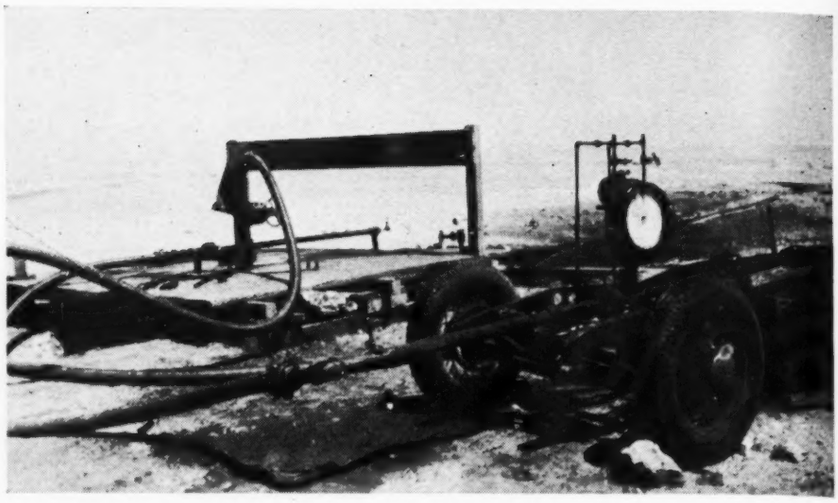


Portable orifice meter hooked-up to a well measuring its oil production

average potential production of 7000 bbl. per day each.

The proven productive area of the Main Pay is 12,000 acres in extent. The crude produced has an average gravity of 33 deg. A.P.I., is of good quality and mixed base.

Prior to October, 1937, all production was obtained from the Second, or Main Pay, the approximate average depth of which is 2200 feet. In October, 1937, a deeper pay was found at a depth of 4150 feet. This is known as the Fourth Pay and, being a prolific producer, it has proved an important discovery that has increased many fold the potentialities of the field. The areal extent of this Fourth Pay has not yet been determined, as only four wells have been completed in this productive zone.

Drilling conditions in the field are, to say the least, peculiarly difficult. From the surface down to a depth of approximately sea-level, boulders are encountered and necessitate the setting of 200-300 ft. of surface casing. No cement is used in setting this string of casing. From this depth (sea-level) down to approximately 1500 ft. is cavernous limestone, which in places contains pockets of tar; both are obstacles in drilling. The limestone is not especially hard to drill, but in the first wells drilled cable tools were used and progress was very slow. It took 30 days to penetrate this thickness of cavernous limestone.

A well that is being drilled-in under pressure using rotary equipment

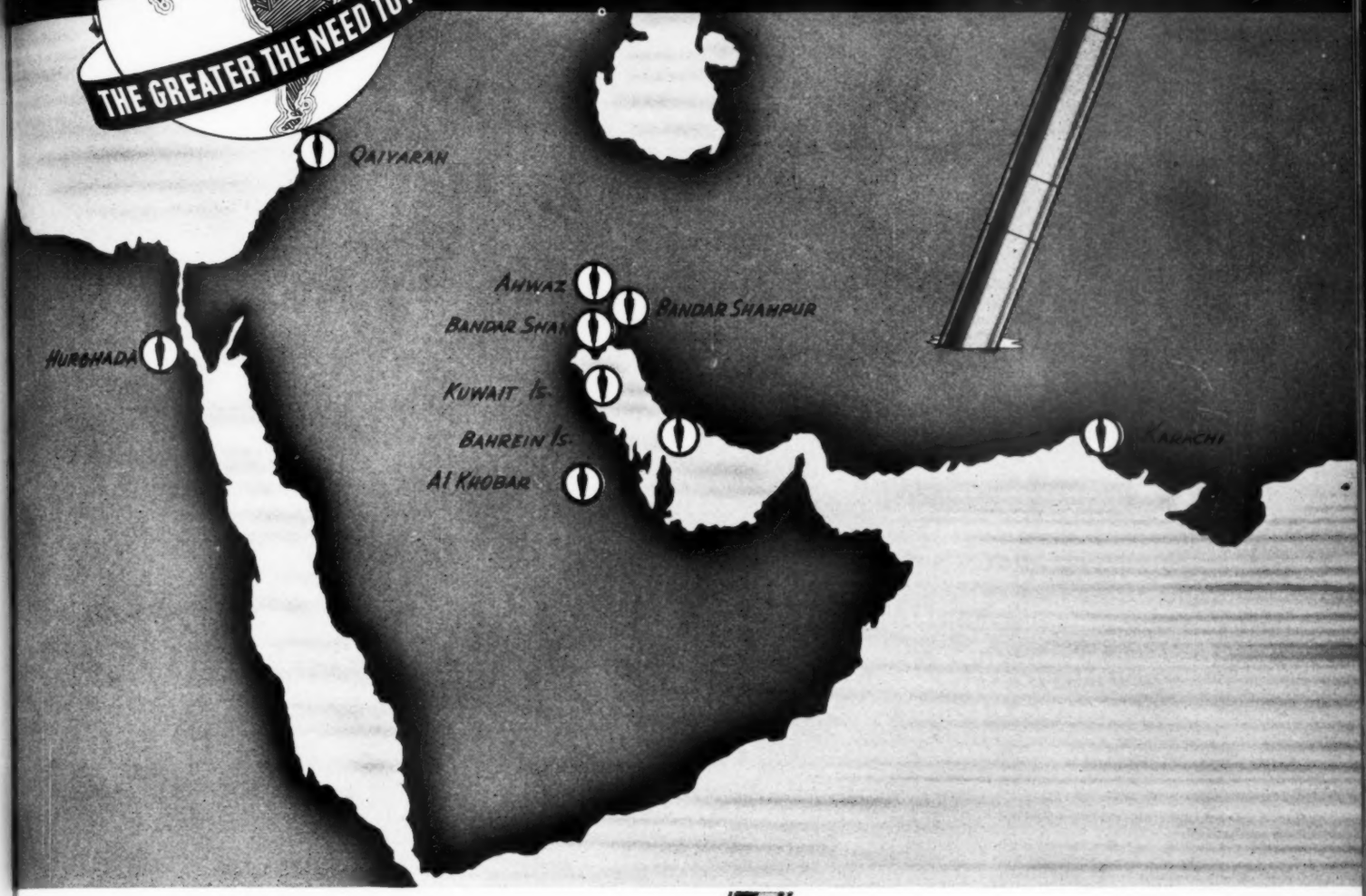
Various types of drilling equipment and drilling methods have been tried in an effort to overcome the difficult conditions encountered. About two years ago, the rotary was used to drill through the cavernous limestone, and although the time of drilling has been reduced from 30 to 7 days, the difficulties have not been entirely overcome. Circulation cannot be maintained and drilling has to be carried on with caution; clear water is used as the drilling fluid. The cuttings are pumped back into the limestone and extreme care has to be exercised to prevent the drill pipe from freezing should the slush pumps for any reason shut down. Stoppage of drilling water will cause the cuttings to settle quickly in the hole, and unless the drill pipe is immediately pulled off bottom, it freezes. As soon as the cavernous limestone is penetrated a string of casing is set and cemented. Another string of casing is set and cemented on top of the Second Pay before drilling-in. One of the former completion methods was to drill into the Second (Main) Pay under pressure. When wells were drilled-in under pressure using oil as circulation fluid, a flow test was made for each 25 ft. of hole drilled to ascertain the productivity of the well.

Rock bits are used entirely, and although the formations (limestone, shale, chert, and sandstone) are not especially hard, there are other difficulties that enter to render drilling extremely hazardous. There are cavities that must be mudded-off with heavy mud. From 2000 to 2400 ft. drilling mud weighing 86 lb. per cu. ft. is used. Of the wells in the Second (Main) Pay, 25 were completed by running the liner under pressure. The procedure was to set a plug in the cas-

Interior of company's machine shop

THE MORE REMOTE THE WELL
THE GREATER THE NEED TO KNOW

NEW riches in ANCIENT land



Map shows Near East locations where one or more Johnston Testers are in constant use saving development dollars!

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"WHY SET CASING BEFORE YOU KNOW!"

Submarine loading line at Sitrah terminal

ing at the top of the Pay into which the well had been drilled under pressure. A liner was then run under pressure on the bottom of the drill pipe and the liner landed by pushing the plug ahead of it to the bottom of the hole.

These difficulties explain why three strings of casing are used in these rotary drilled wells 2400 ft. deep. The casing program for Second Pay wells was:

13¾-in. A.P.I. casing set at 250 ft. —no cement.

9-in. A.P.I. casing set at 1550 ft.—150 sacks cement.

6⅝-in. A.P.I. casing set at 2000 ft. —150 sacks cement.

4¾-in. slotted liner from 2000-2400 ft.

The present casing program for Second Pay wells, which involves drilling through the Second Pay with weighted mud and setting a full string of 4¾-in. casing, is as follows:

11¾-in. A.P.I. casing at 250 ft.—no cement.

7-in. A.P.I. casing at 1550 ft.—150 sacks cement.

4¾-in. A.P.I. casing at 2400 ft.—150 sacks cement.

In completing wells with a full string of 4¾-in. casing, blank pipe is used opposite the pay sand. This is gun-perforated opposite the face of that part of the Pay from which it is desired to produce.

Wells drilled to the deeper Fourth Pay encounter even greater difficulties than the shallower Second Pay wells. Aside from the difficulty of maintaining a good hole through the cavernous limestone already discussed, cavities are encountered in the formation below the Second Pay. There is difficulty in maintaining circulation. Circulation is frequently lost and cannot be re-established. There are also two zones that carry hot salt water in large volume. Below 4000 ft. there is also a productive high-pressure zone 600 ft. thick that contains gas, water, and oil under a pressure of 2000 pounds. So severe are the underground conditions encountered in drilling that it is necessary to use five strings of casing in the Fourth Pay wells. The casing program in use is as follows:

21½-in. A.P.I. casing, 250 ft.—no cement.

16-in. A.P.I. casing, 1550 ft.—150 sacks cement.

11¾-in. A.P.I. casing, 2450 ft.—150 sacks cement.

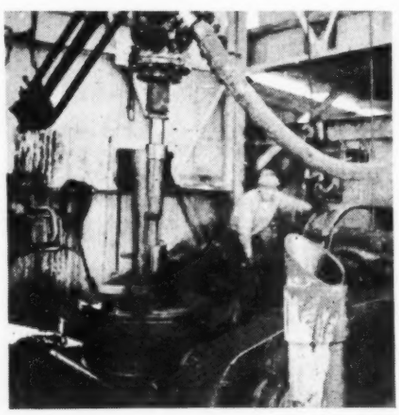
8⅝-in. A.P.I. casing, 2850 ft.—250 sacks cement.

6⅝-in. A.P.I. casing, 4200 ft.—300 sacks cement.

4¾-in. Securaloy blank liner, 4200-4900 ft.—175 sacks cement.

Formation tests and electrical log surveys are made while drilling-in. Selective completion of wells is found necessary.

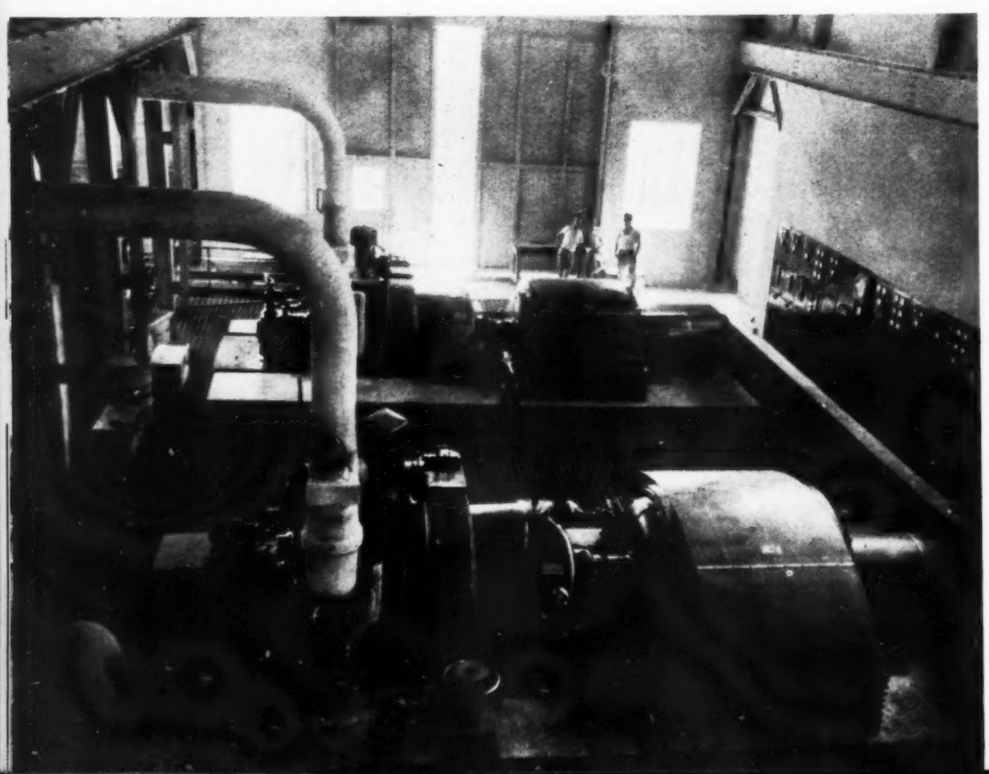
Temperature surveys show the temperature gradient to be high—one deg. per 30 ft. of depth. The fluid temperature at 2200 ft. is 155 deg. fahr. and at 4400 ft., 200 deg. fahrenheit. On account of the high temperature, slow-setting cement is used for cementing casing.



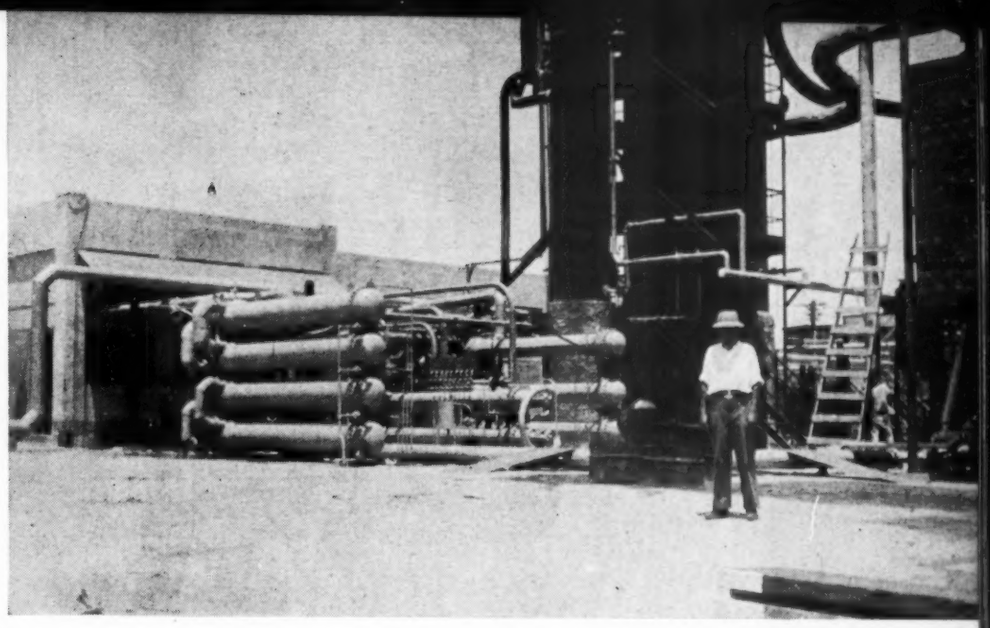
Drilling under pressure

All drilling is now done with rotary tools, and rock bits are used entirely. Reaming is sometimes necessary in landing casing and for this purpose a special rock-bit reamer of ingenious design is employed.

Some trouble has been experienced with mudding-off of the face of the



Turbine units and switchboard, Bahrein power plant



Distillation unit at refinery

pay, resulting in interference with the flow of oil into the hole. To overcome this trouble the use of a special mud that can be removed by acidizing is being tried.

Withdrawal of oil from the reservoir is under strict engineering control. If undue quantities of water appear in an edge well, production from that well is heavily restricted. An isobaric map is maintained to show the lines of pressure in the reservoir. These lines of pressure are plotted from bottom-hole test data. Pressure lines are kept as uniform as possible; any irregularity is immediately detected and remedial steps taken to remove it by adjusting the rate of flow from individual wells. The outside wells on the structure are maintained at a higher bottom-hole pressure than the inside wells (wells on the crest of the structure). Better control of edge water encroachment is thus obtained.

Individual gauges of production by portable meter are made at regular intervals on all wells, and also bottom-hole pressure - production - temperature tests. All wells are acidized, but not before the productivity index of the well is determined. An average increase in production of 200 percent has been obtained by acidizing.

Tests show that the smaller the productivity index of the well the greater the increase in production by acidizing. For example:

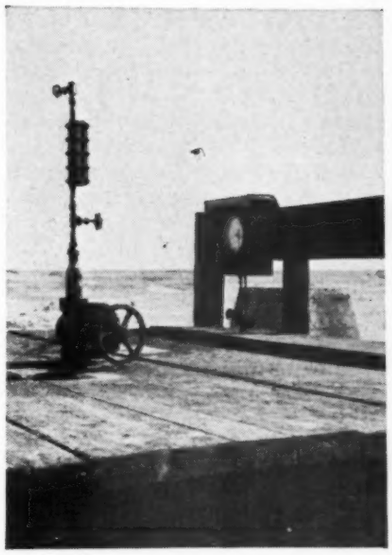
Productivity Index of Well	*Increase in Production*
20	60%
10	125%
5	250%
2	550%
1	1000%

The productivity index and the well penetration are factors governing the amount a well's production is restricted. Underground water surveys are made periodically in wells by means of a water witch.

The average gas/oil ratio of wells in the Second Pay is 125 cu. ft./bbl., and of wells in the Fourth Pay, 500 cu. ft./barrel. Saturation pressures of the oil are closely studied and utilized in producing operations.

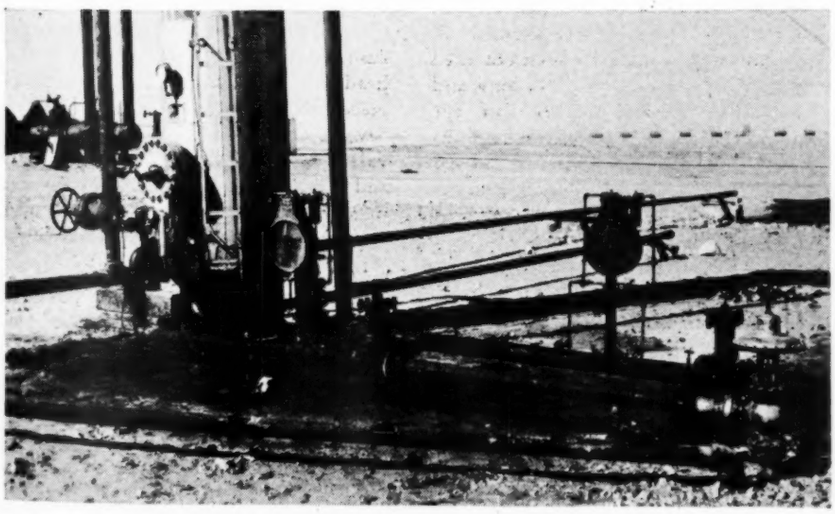
All production from the wells is flowed through common flow lines, the sizes of which range from 2-in. to 6-in., to central gathering stations. There are five of these stations in the field and each receives the production from ten wells. At these stations the oil and gas are separated by means of a common degassing system.

The possibilities of pressure maintenance are now being investigated. High-pressure gas from the Fourth Pay is being injected through a well into the Second Pay at the rate of 3,000,000 to 9,000,000 cu. ft. daily. A marked reduction in the rate of reservoir pressure decline in the Second Pay has been observed.



Gauge glass for obtaining saturation pressure

The fact that this field is being developed as a unit, and that all drilling and producing operations are under thorough engineering control, facilitates the application of advanced scientific methods in the production of oil. The results obtained over a period of years, when made available, should be such as to hasten adoption of similar methods in other fields.



Trap and connections with oil meter and gas meter. Oil is metered at trap pressure.

One Richly Productive Field in Iraq Merely Indicates the Potentialities of the Country

Perfection of a method of removing excessive sulphur must precede extensive development of other areas, however

By RALPH H. KING

A GEOSYNCLINE occupies the southwestern part of Iran and the northeastern part of Iraq. Forces thrusting from the northeast have folded the strata in the geosyncline into parallel ridges trending northwest-southeast. The anticlines in the southwestern part of the basin are moderately folded and symmetrical, those near the center are sharply folded and asymmetrical, and those in the northeastern part are overthrust and the strata overturned.

The oil fields are situated on the local anticlines and the most productive areas thus far discovered are those situated on the narrow, asymmetric folds near the center of the basin, in both Iran and Iraq. The reservoir rock is a resistant limestone but the overlying formations are incompetent beds and on many structures these overlying strata have been crumpled and overthrust, masking the attitude of the underlying limestone. In Iraq the productive limestone is known as the Main Limestone and consists of Eocene and Oligocene strata as well as the lower Miocene Asmari limestone, which is the productive zone in most of the fields of Iran.

Kirkuk Field

The most important field in Iraq is the Kirkuk field, which is, in fact, one of the most important in the world. Near it are the Eternal Fires mentioned in the Old Testament, and probably the first petroleum used by man was obtained from nearby seeps. The field is important, however, because of its great reserves and large potential production.

The reservoir consists of three domes on the crest of an anticline. The productive portions of the Baba Gurgur and Avanah domes are continuous over a length of 50 miles. The Khurmala dome will produce gas but is not now producing. The average width of the productive area is two miles. The central dome is entirely separated from the Khurmala dome and almost separated from the other by relatively long saddles. Depth of the wells ranges from 1200 to 4000 ft. depending upon topography and structural position. Gravity of the oil is 30 to 33 deg. A.P.I.

The discovery well, Iraq Petroleum Company's Baba Gurgur No. 1, was completed in October, 1927, but development was not attempted until the Iraq government granted a revision of the concession in 1931. Prior to that time the Iraq Petroleum Company had held blocks scattered throughout the country but the revision granted it the right to exclusive exploitation of the vilayets of Baghdad and Mosul. Between 1933 and 1936, wells were drilled to delimit the Kirkuk field and to permit observation of gas-oil and water-oil contacts, reservoir pressure, and other reservoir conditions. Only one dry hole was drilled and it was off the structure. During these years the production equipment was installed, a stabilization plant was erected, and the pipe line to the Mediterranean ports of Haifa and Tripoli was constructed.

Inasmuch as the Iraq Petroleum Company controls the entire field, all operations have been arranged to produce oil as economically as possible. All oil thus far produced has been obtained from an area about ten miles long and two miles wide on the crest of the main dome. By 1937 a total of 46 wells had been drilled, of which only 14 are producing oil, the rest being observation and control wells, some of which were drilled in delimiting the field and some of which were specially drilled for the purpose. The distance between wells averages approximately 1.5 miles, the wells on the southwest flank of the structure being somewhat more closely spaced and those on the northeast flank somewhat less.

The scheme of producing oil from only the small area on the crest of the central dome permits maximum economy of operation and permits use of a minimum amount of flow lines and other surface equipment. Without difficulty the producing wells provide 80,000 to 86,000 bbl. of oil per day, which is the capacity of the pipe line that transports the oil to the coast.

The first wells were drilled by cable tools but rotary rigs have been adopted exclusively for recent drilling. Steam-driven rigs are used, a plentiful supply of water being obtainable from Lesser Zab River, which crosses the field.

Drilling of most wells is begun using 8-in. drill pipe and 20½-in. rock bit. At a depth of 150 ft. the 65-lb. 16-in. casing is set and cemented to surface and a blowout preventer is installed. A 14⅞-in. rock bit or drag bit and 6-in. drill pipe are used in drilling to a persistent anhydrite bed near the base of the Lower Fars series, on which the 45-lb. 11¾-in. casing is set and cemented to surface. A 10½-in. rock bit or pilot bit and 4½-in. drill pipe are used to drill to the top of the Main limestone, where 32-lb. or 38-lb. 8⅝-in. liner is set and cemented to the shoe of the 11¾-in. casing. The Main limestone is drilled or cored by 7⅞-in. bit on 4½-in. drill pipe.

Above the master gate valve the casing is reduced to 6-in. and the well head fittings consist of a special Y-piece and long bend to reduce friction. Several small pipes equipped with valves by-pass the main 6-in. valve, and are used for regulating production to the desired amount.

No separators or tanks are provided at the wells. Each well is connected by its individual flow line to one of three de-gassing stations. Oil flows to the de-gassing stations under well pressure. The flow lines are laid on the surface of the ground at as nearly uniform a grade as is possible.

The de-gassing stations were built

(Continued on Page 106)

"SAY, BILL, HOW CAN YOU HANDLE THIS BIG RIG WITH ONE BOILER? THAT OUTFIT OVER THERE IS USING THREE AND FIRING HEAVY."
"THIS IS MORE THAN A BOILER, JACK, IT'S AN 'OILWELL' SUPER-HEATED STEAM GENERATOR!"

AND you'll be surprised, too, when you try out a complete "Oilwell" Steam-Saving Rig for the first time. Every unit saves steam. The new "Oilwell" feedwater heater pump, the engine-driven power pump, the direct-driven rotary and the superheater on the steam generator—all combine to reduce fuel and feedwater consumption to about one-third that of the ordinary rig.

OIL WELL SUPPLY COMPANY

Subsidiary of United States Steel Corporation

Branch Stores in all Oil Fields

"OILWELL"

(Continued from Page 102)

at elevations higher than the producing wells. They were designed for either flash or two-stage separation, the high-pressure stage being 120 lb. per sq. in. and the low-pressure stage a few inches of water. Each station is provided with two high-pressure separators and two flow tanks for low-pressure separators. One set of separators is used as a standby and also in testing the productivity of individual wells. The high-pressure stage can be by-passed if that is desirable. The rate of production is 85,000 bbl. per day, and any two de-gassing stations can supply this quantity, should it be necessary to suspend operation of the third.

In September, 1936, a stabilization plant was installed, necessitating a change in de-gassing procedure. The high-pressure separators now discharge into the gravity lines that transport the oil to the stabilization plant, and the flow tanks are used only for gauging well production. The oil is delivered to the stabilization plant at a pressure of 50 lb. per sq. in. or more, and the second-stage separators remove any remaining gas at 50-lb. pressure.

The stabilization plant consists of three units having a capacity of 40,000 bbl. per day each, so that any two can process the required amount of oil.

Oil is processed in two stages. In the first stage the crude is topped, the light distillates are partly fractionated, and the undesirable sulphur compounds are removed. In the second stage the light distillate and vent gases from the first stage are fractionated. The topped crude is blended with the stabilized distillate and piped to the coast. The vapors are used as fuel or piped to a burning point.

The oil produced in the Kirkuk field is transported through combination 8-in., 10-in., and 12-in. pipe lines to Tripoli in Lebanon and Haifa in Palestine, two ports at the eastern end of the Mediterranean Sea. The lines are parallel as far as Haditha on Euphrates River, and there diverge. The distance from Kirkuk to Haditha is 150 miles. The distance from Haditha to Tripoli is 382 miles and to Haifa is 470 miles.

The pipe line traverses very broken country and the elevation varies greatly. At Kirkuk the elevation is 1013 ft.; at Wadi Tharthar west of Tigris River it is only 200 ft.; at Mile 466 on the north line it is 2500 ft.; at Mile 451 on the south line it is 3150 feet. In the rift valley of Jordan River south of Galilee the elevation is 850 ft. below sea level. Extra heavy 8-in. pipe was laid and a pressure-relief station was constructed at this point.

The line was welded, coated, wrapped, and, over much of the route, buried 30 in. beneath the surface in solid rock.

There are twelve pumping stations, and the three on the first 150 miles of the line are double, as the line is double. Each single station houses three 500-hp. Diesel engines flexible-coupled to reciprocating pumps. Crude oil is used as fuel in the engines. The capacity of each unit is at least 21,000 bbl. per day, so that of the line is 84,000 to 85,000 bbl. per day.

At each sea terminal the pressure is sufficient to load a ship at the rate of 1000 tons per hour and ample storage is provided. Loading facilities at Haifa consist of an oil dock and two sea lines, and at Tripoli tankers can be loaded through three sea lines.

A complete telephone, telegraph, and teletype system connects all stations along the line with both terminals and with the field. A new highway follows the entire right-of-way of the southern line.

Qaiyarah Fields

South of Mosul the Mosul Holdings, Ltd., controls a large concession in which 17 structures have been tested. Most of the wells were drilled on the Qaiyarah-Najmah-Jawan structure, a large anticline 23 miles long and 2½ miles wide. The main producing formation is the Asmari limestone, which is reached at an average depth of 1000 feet, but some slightly lighter oil has been found at greater depth in the Pilsner (Upper Cretaceous). Altogether 54 wells have been drilled in this area and satisfactory reserves established to warrant development. The quality of the oil produced, however, is poor; the gravity of the oil is 16 deg. and the sulphur content exceeds six percent. The viscosity greatly exceeds that of most crudes of the same gravity.

Two strings of cable tools are drilling wells to develop the structure. The casing program is the same as that of the Kirkuk field except that the oil string is 6⅝ in. or 5¾ in. The productive strata are more nearly level than they are in the Kirkuk field, hence the oil-water contact is broader and less sharply defined, so water troubles are anticipated in the future.

At present distillates obtained from oil produced in Iraq are being treated for the removal of sulphur by the addition of 0.07 to 0.15 percent elemental sulphur in the presence of five to ten times that much 25 percent caustic soda solution.[1]

A suggested process involves agitation to mix the oil thoroughly with very finely divided copper to remove the sulphur as copper sulphide. The copper would then be recovered by roasting, the sulphur dioxide thereby produced being converted to sulphuric acid, pyrites, or copper sulphate, and marketed. Distillation of oil containing some copper would produce a gum-free product.[2]

Other structures in this vicinity that have been tested include Qalian, where a test well has already been drilled to a depth of 7000 ft., Alan, Gusair, Ain Zalah, Hibbarah, and Sadid. An exploratory well is being drilled on the large Makhul structure, which is a continuation of the larger Jebel Hamrin structure.

Most of the exploratory wells are drilled by heavy rotary rigs. Water is very scarce, so Diesel power is used, and the necessary water is piped from the river. The great seasonal variation in the water level in the river has necessitated building some of the pumping stations on barges. Locally gas for fuel can be obtained from shallow formations.

Naft Khaneh Field

The reservoir rock in the Naft Khaneh field is not typical of the Iraq fields nor of the Iran fields. Most of the oil is obtained from thin limestones interbedded with shale and anhydrite in the base of the Lower Fars, but some comes from the underlying Kalhur limestone, which is equivalent to the upper part of the Asmari limestone of the fields of Iran and to the uppermost part of the Main limestone of the Kirkuk field. In short, in this field oil is obtained from formations somewhat younger than any that produce in other parts of the basin.

The field is operated by the Khanaqin Oil Company, Ltd., a subsidiary of Anglo-Iranian Oil Company, Ltd., and the oil is refined and marketed locally by Rafidain Oil Company, Ltd.

Oil was first produced in 1927 and since development was completed production has averaged about 575,000 bbl. per year, which is less than 1600 bbl. per day.

The fields and pipe lines of Iraq are shown with those of Iran on the map on page 164.

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[1]Processing of Sulphurous Iraq Crude, by M. Morgenstern. Petr. Z., Oct. 1, 1937, 33 (39), 31.

[2]Desulphurizing Irak Petroleum with Finely-Divided Copper, by C. Baron. Ann. des Comb. Liq., 1937, 12, 25-28.

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EXCELLAY Preformed Rotary Lines are constantly growing in popularity for one important reason—*economy*. We have recommended that users of Excellay Preformed Rotary Lines keep ton-mile service records and, where this has been done, the result has always been further proof of the economical service Excellay Preformed Rotary Lines can give.

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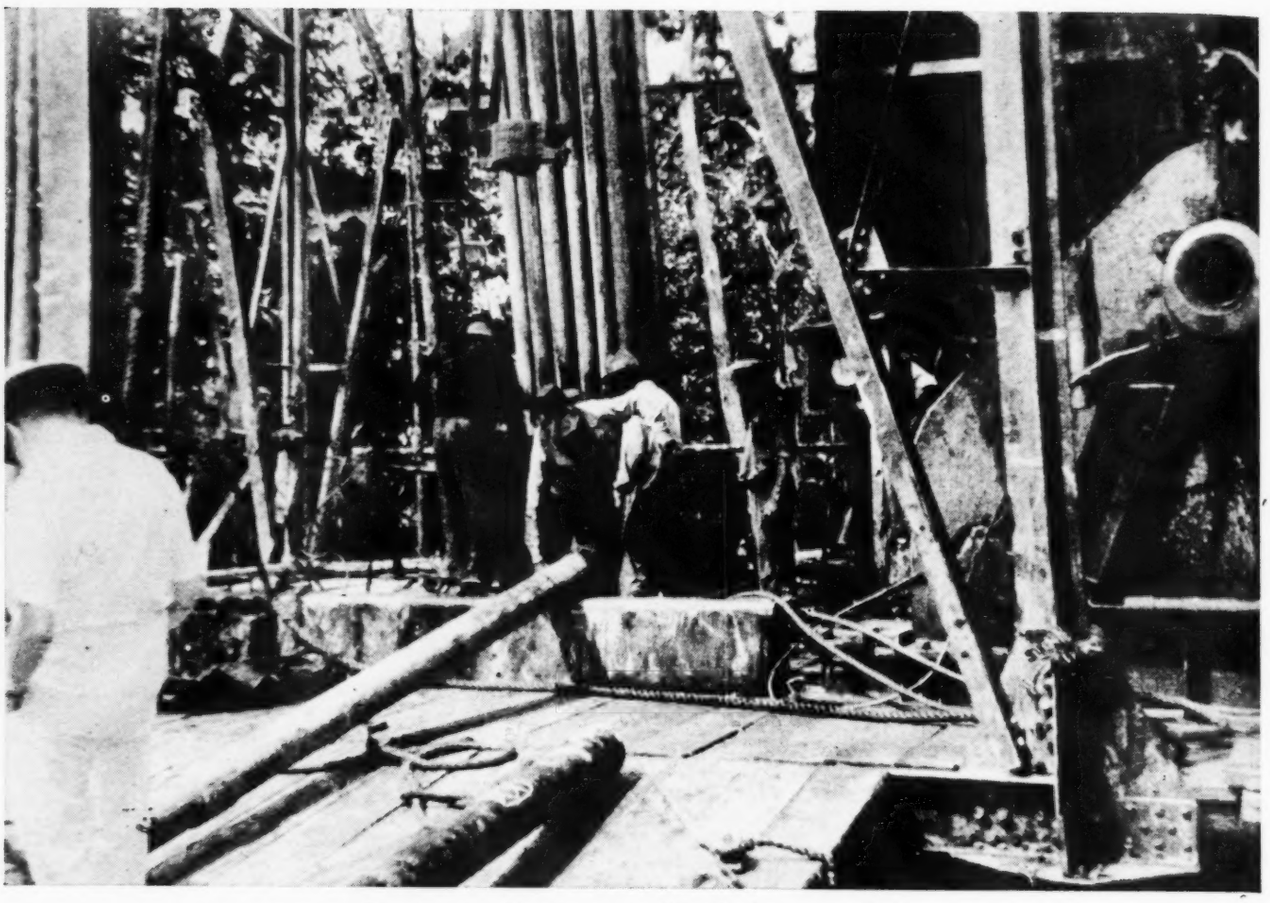
UNITED STATES STEEL



Running an oil string in a well in the Kawengan field

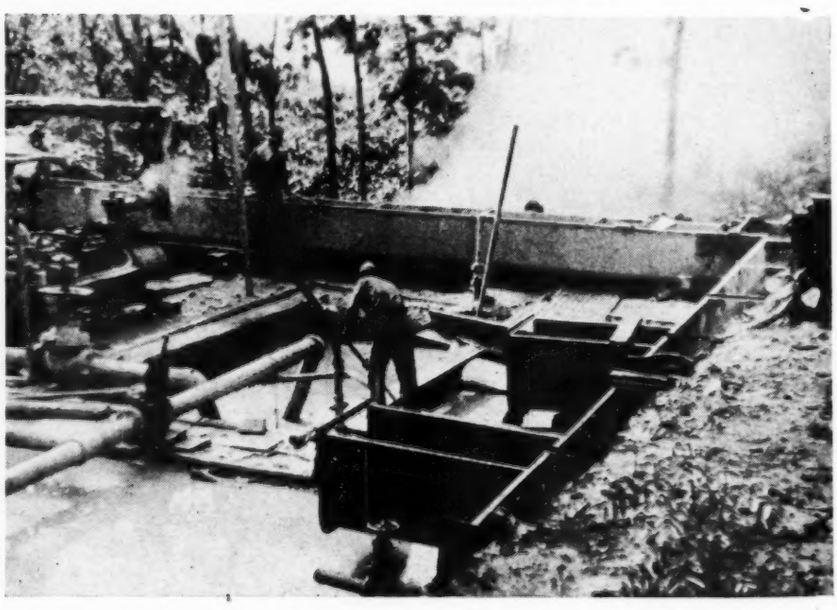
Drilling and Production Practice in Java

Wide spacing pattern contributes to maintenance of natural flow of wells

By JOHN F. DODGE and WALLACE A. SAWDON

AT present oil is being produced in Java only at the eastern end of the island. Standard Oil Company of California recently drilled a wildcat in the western part less than 100 miles from Batavia but abandoned it at a depth of 8170 feet. The equipment used is now being shipped to the Rokan Block in Sumatra and a medium heavy rig will be imported for further tests in western Java. The southern half of the island is mountainous and the rocks are volcanic in origin, hence only the northern coast offers any possibility of oil production. Virtually all the oil is being produced from the district around Tjepoe, about 30 miles from

(Continued on Page 111)



Steel ditches for mud settling such as the one here shown are widely used by the Shell in operations in Java

Mixing rice hulls for recovering lost circulation in a well in Java

(Continued from Page 108)

the coast and 100 miles west of Soerabaya. Tjepoe can be reached by train but is generally reached by car either from Batavia (about 300 miles) or from Soerabaya. The Shell Oil Company has a refinery at Tjepoe and moves the products by rail to Soerabaya for shipment.

Koloniale has a small field producing less than 200 bbl. per day near Batavia but it is unimportant.

According to Ely[1] in the producing fields of East Java, which underlie an area approximately 75 miles long and 25 miles wide, the oil is obtained from sand lenses in the Middle and Lower Rembang formations of Lower Miocene age. (See stratigraphic column.) The structures are sharply folded and faulted anticlines. The most prolific pools occupy a central zone, bordered on both north and south by less productive anticlines.

Three fairly well defined zones paralleling the north coast are, from north to south, as follows:

"1. Coastal zone of marls, clays, chalky limestone, and sandy limestone with numerous coal seams. Some gas is produced. The width of this zone is from eight to twelve miles.

The steel ditches carry the returns to the suction pit. A well in the Kawengan field, Java

"2. Middle zone of chalky limestone (rich in corals) interbedded with clay and sandy limestone. No coal and no commercial oil or gas. The width of this zone is from six to eight miles.

"3. Southern zone of impure limestone (Platten calc) interbedded with marls and sandstones and in certain areas overlain by thick deposits of blue and black marls. Most of the production is within this zone, which is from 12 to 15 miles wide. This zone on the south merges into the more closely folded sediments intruded by volcanic rocks and terminating in the southern volcanic mountain chain. The gravity of the oil varies from 27 deg. to 47 deg. Baumé."

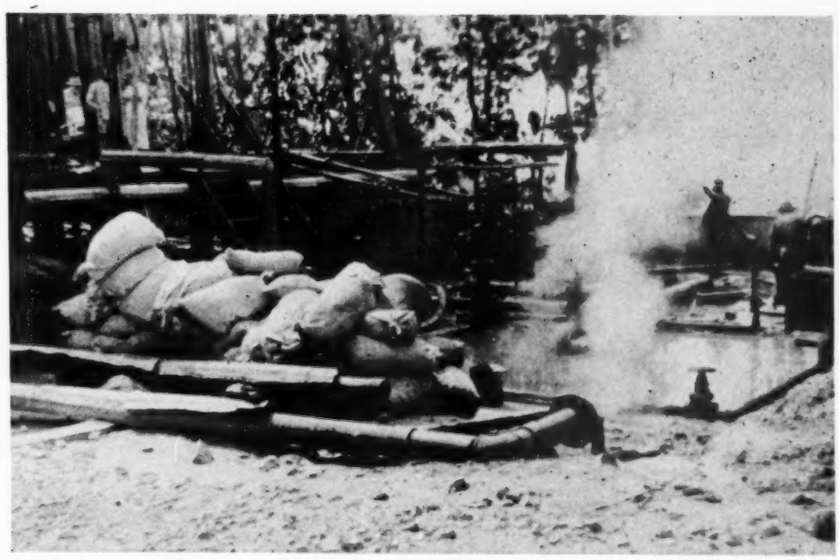
Tjepoe

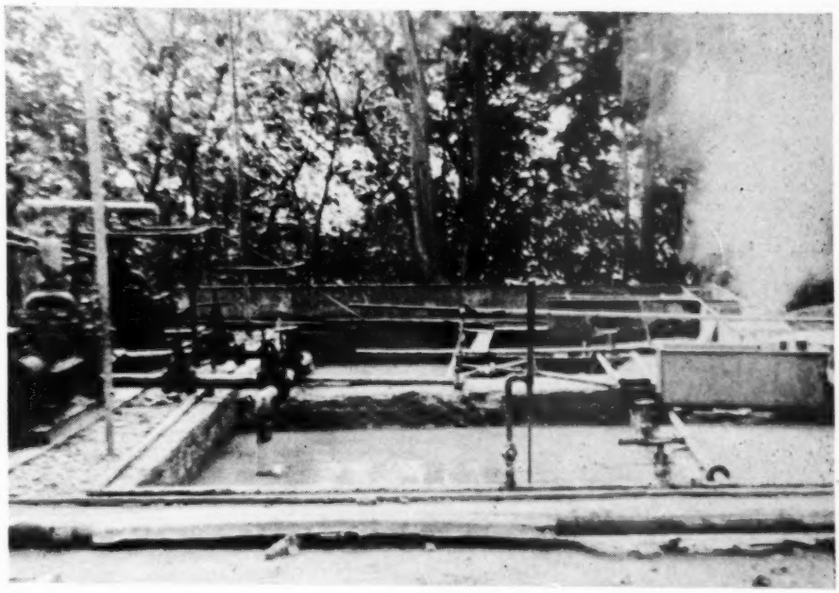
Oil was first produced from the

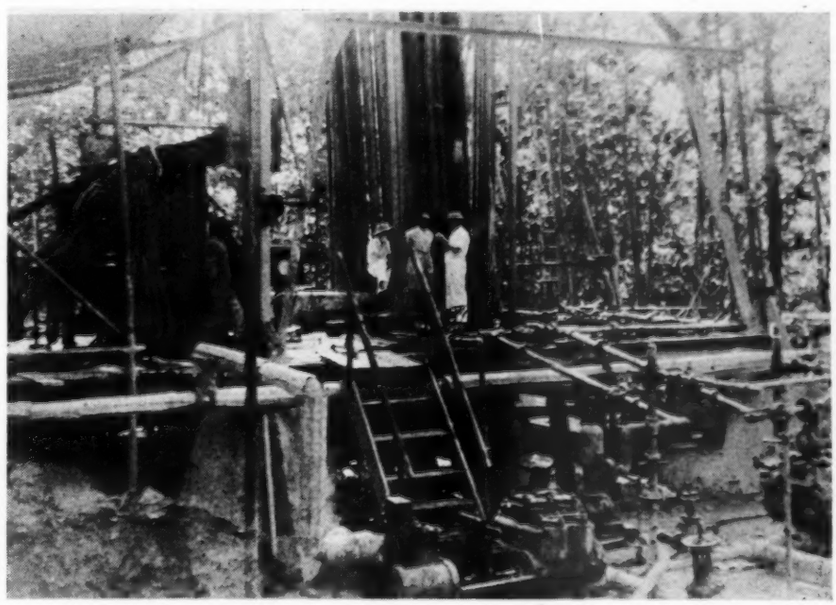
[1]Petroleum in the Dutch East Indies, by Fred B. Ely. Trans. Petroleum Division, A.I.M.E., 1931.

(Continued on Page 114)

A Shell well in the Kawengan field near Tjepoe, Eastern Java. The man in white wearing the lion-tamer's hat is "Frosty" Martin







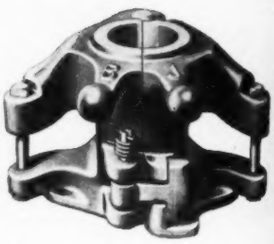
OVER-SEAS, BJ TOOLS

The patented "locking-arm" gives all BJ Rod Hooks an extra measure of safety. Made in 3 types, or sizes, including a "spring type" for the longest rod strings.

The BJ Shortype C Tubing Catcher is designed for wells of average depth, and is priced so low that even the shallowest wells cannot afford to be without one.

BJ Tubing Hooks are made with enclosed relief springs for 75-ton loads, for 50-ton loads (at left); and without spring for 30 tons (right).

BJ Surestop Tubing Catchers protect your tubing when running-in or coming-out, and while suspended in the well. The BJ Anchoring Method stops collar wear due to "tubing breathing" and provides more efficient operation of the pump.

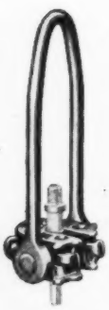


This light-weight, Open End Tubing Tong is easy to handle, and amply strong for ordinary work.

The BJ Snapon Tong encircles the tubing and locks in place. A back-up lever makes it easy to correct cross-threads without removing tong from tubing.

For tubing strings of ANY size and ANY length, you can depend upon BJ (Wilson Type) Center Latch Elevators.

When tubing strings are long and heavy, don't take chances: BJ Weldless Links (1¾" diameter by 36", 48" or 60" in length) carry the load safely.



The Full Circle Rod Elevator fits only one rod size, and in service wears to a taper which suspends the rod in a true vertical and balanced position. It is fast in operation, and a standard for safety.

Each BJ Rod Elevator handles two sizes of rods, and is equipped with both front and rear operating latches. Made in a Light and a Heavy Type, both are convenient to use and do not kink rods.

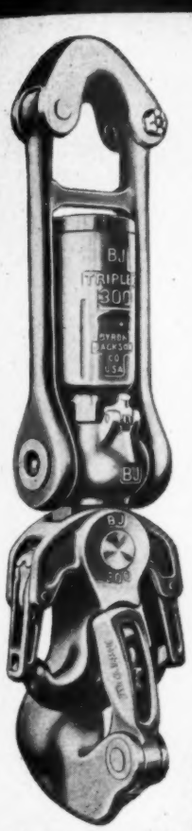
THE BJ SECTION IS ON PAGES 444 TO 512 OF THE 1938 COMPOSITE CATALOG

PRODUCTION TOOLS

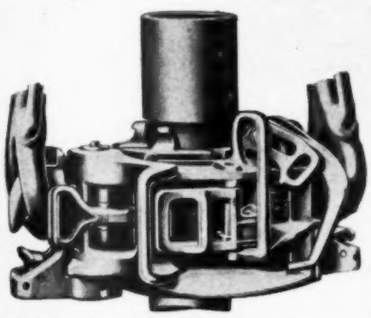
The Armco-International Corp.,
222 Corrientes,
Buenos Aires, Argentina

W. C. Langley,
Port of Spain
Trinidad, B.W.I.

S are ALWAYS PREFERRED

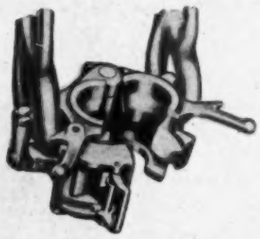


Drilling crews "prefer" BJ Triplex Hooks because of the separate hooks for each elevator link, and the swivel bail—all equipped with safe "locking arms" which provide extra strength and safety not otherwise obtainable. Why not give your crews these modern advantages?



BJ Side-door Slip Elevators are easily removed while the cement is setting. They carry the load on four long slips, without lifting under the collar or coupling; they are easy to operate; and are safe for the longest, heaviest strings.

The fully heat treated body of this BJ Type A Center Latch Elevator does not upset under the pounding action of tool joints contacted at high speed. The protected latch—long guarded horns, and other features make it a favorite everywhere for handling drill pipe.



This new BJ Rotary and Casing Tong is an Extra-Heavy Type, fast in regular service, and amply strong for breaking out drill collars and other heavy duty service. Perfect contact all around the pipe permits BJ Tongs to grip securely without crushing.

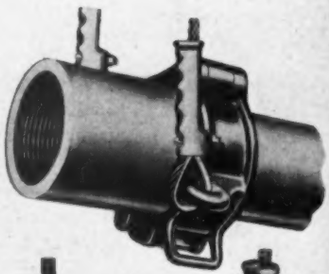
The BJ "100" Triplex Hook (above). Widely used where loads up to 100 tons are carried.

BJ Single Joint Elevators replace unhandy and dangerous rope slings for "tailing in" the next joint of casing. The Type J (at right) is for collar type pipe; the Type P (below) has slips for handling external upset (5°) casing. See page 465, 1938 Composite Catalog.

The BJ "50" Triplex Hook (above) meets the demand for a light-weight hook for portable rigs, exploratory drilling and drilling in with tubing. The over-all length of only 71 inches makes it the perfect hook for use in short derricks.

For handling external upset drill pipe (of standard 18° taper) without using lifting plugs, specify the BJ Type G Elevator; for side door operation specify Type B.

The acknowledged leader for handling casing, BJ (Wilson Type) Side Door Elevators, are made all pipe sizes from 2⅜" to 24½" in diameter.



BJ DRILLING TOOLS

John H. Baird,
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New York, N. Y., U. S. A.

2105 East Slauson Ave.,
Los Angeles, California
6247 Navigation Blvd.,
Houston, Texas

TABLE I

Age in years to end of 1937	50
Total bbl. oil to end of 1937	86,126,191
Total bbl. oil during 1936	3,774,955
Total bbl. oil during 1937	7,198,446
Average daily, December, 1937	19,452
Average daily, per well, December, 1937	44
Total gas, million cu. ft., 1936	2808
Total gas, million cu. ft., 1937	4526
Wells completed to end of 1937	*
Completed during 1937	*
Abandoned during 1937	6
Temporarily shut down at end of 1937	79
Producing oil only at end of 1937	440
Average depth in ft.	160-2950
Average depth to top of producing zone	130-2880
Flowing wells at end of 1937	36
Pumping wells at end of 1937	401
Gas-lift wells at end of 1937	3

*Included with South Sumatra.

Stratigraphic Column—North Central Java[1]

Period	*Formation*	*General Description*
Pliocene		Clay marls—no oil.
Miocene	Upper Rembang	Sandy marls. Thin limestones and sandy limestones. Interbedded marls and marly shales called globigerine marl zone.
		Lower part well stratified.
		Amphistignia carbitina—Pulvinulina—Rotalia.
		No oil.
		Thickness 1400-1500 feet.
	Middle Rembang	Limestones and sandy marls (Platten calc formation), also reef limestones.
		Coral and lithothamion limestone.
		Interbedded limestone, sandy shale, and sandy limestone.
		Rich in foraminifera.
		Very little oil.
		Thickness 1400-1500 feet.
	Lower Rembang	Lime clay group—chiefly marls, clay, and shales
		Called Wonotjola marls.
		Most important oil horizon.
		Thickness 1900-2000 feet.
Oligocene		Not differentiated.
Eocene		Limestones in highly folded mountain area.

(Continued from Page 111)

fields around Tjepoe about 50 years ago. Production from this area increased from 3,774,955 bbl. in 1936 to 7,198,446 bbl. in 1937, and total production to the end of 1937 was 86,126,191 barrels.[2] The daily average production for 1937 was 19,452 bbl., and although the average production per well for the entire area was 44 bbl. per day, most of the oil came from the Kawengan field. Gas production was 4526 million cu. ft. in 1937 as compared to 2808 million cu. ft. in 1936. These and other data are given in Table I.

Of the several fields around Tjepoe, only one, Kawengan, is of any importance at present. It is situated about ten miles north of Tjepoe, toward the ocean, and is a long, narrow fold, nearly flat on the north side and steeply folded, possibly over-turned, on the south. Fifty-two wells have been drilled, all on the crest, and spaced 200 to 250 meters apart. All the wells are produced by natural flow or by gas lift. The present quota is somewhat less than 20,000 bbl. per day. The wells are 2700 to 3000 ft. deep, and require about three weeks to drill. No trouble is experienced in drilling, except occasionally circulation is lost in a zone of fractured lime and sand immediately above the oil zone. Rice hulls and thick mud have been used to regain lost circulation.

The casing consists of a surface string, a water string set at a depth of about 2700 ft., and an oil string perforated with round holes ¼ in. in diameter. A 75-lb. mud made from surface clays is used and weight material is never needed. Two strings of tools are being used on exploitation work at present and usually at least one wildcat well is being drilled.

One well recently completed in the Kawengan field had to be pumped. Water encroachment is causing concern and it is anticipated that a repair program must be inaugurated next year.

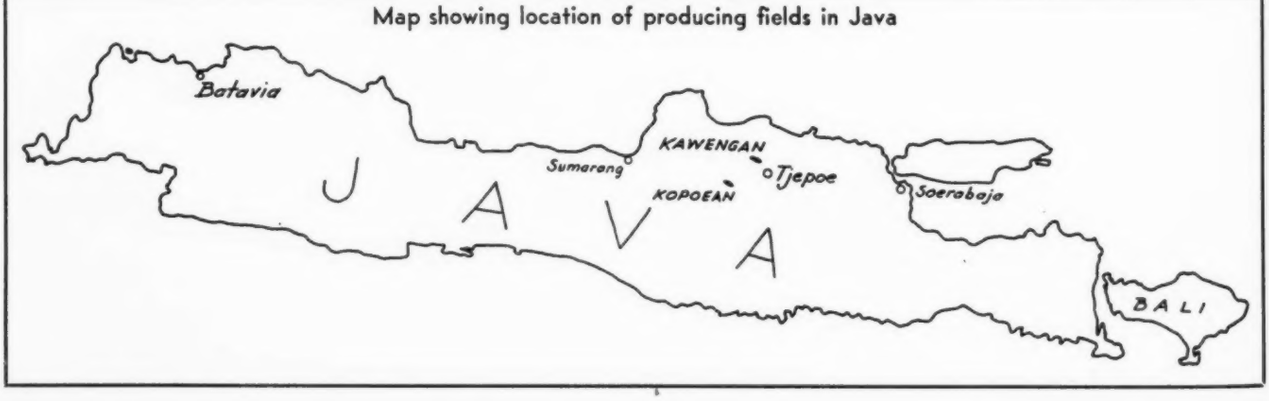
On the B.P.M. Administration at Tjepoe there are approximately 450 producing wells. One deep test is being drilled at Towean, which is about 30 miles from Tjepoe and across the valley from the Kawengan field. This test when visited had been drilled to a depth of 7000 feet.

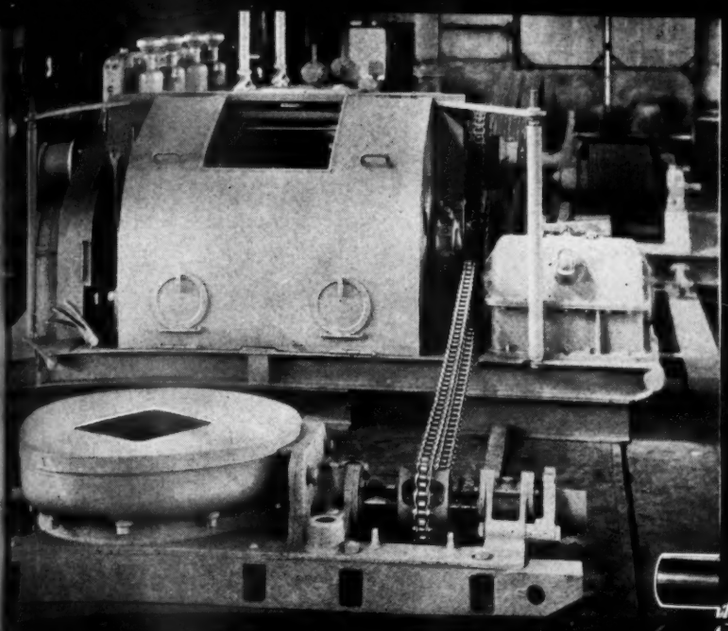
The other old producing fields in this area are Ledok, Nglobo, Lidah, and Kroeka. All these are operated by B.P.M. At Kopoean, Nederlandsche Koloniale Petroleum Maatschappij produces 160 bbl. per day from 20 shallow wells. These wells make considerable water. A small refinery makes gasoline, kerosene, and wax from this crude.

The N.K.P.M. is also drilling a test near Lodan, 55 miles west of Tjepoe, and is planning soon to drill another wildcat well 80 miles east of Tjepoe.

[2]Figures from A.I.M.E. Petroleum Development and Technology, 1938.

Map showing location of producing fields in Java





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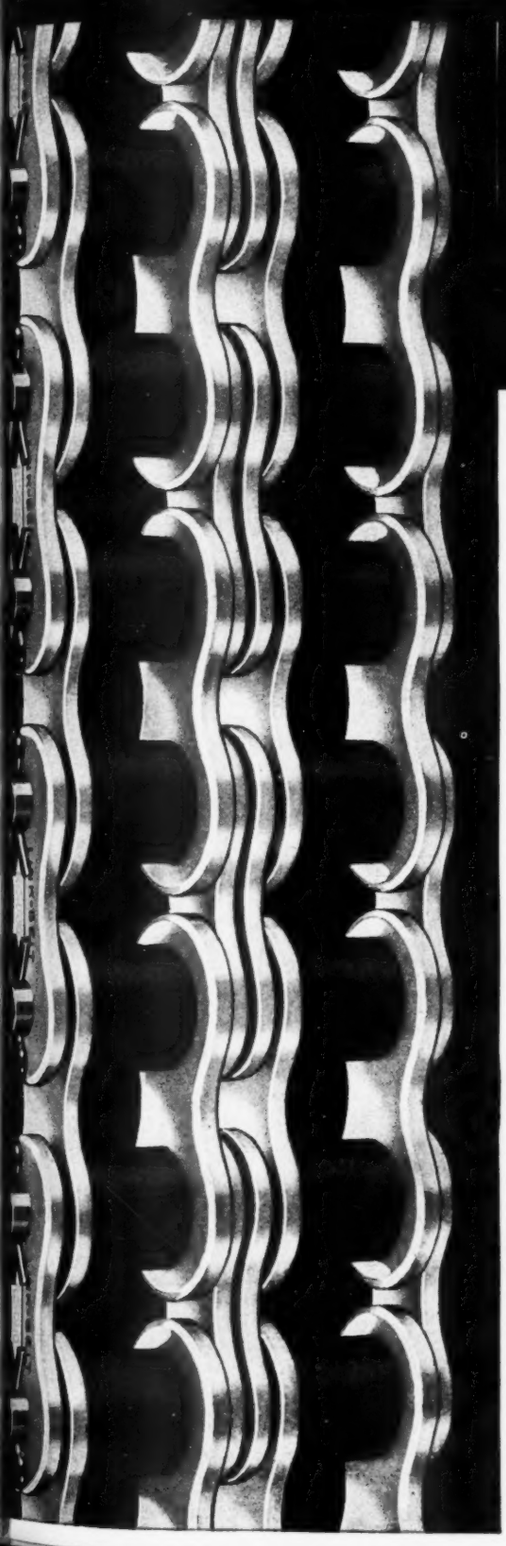

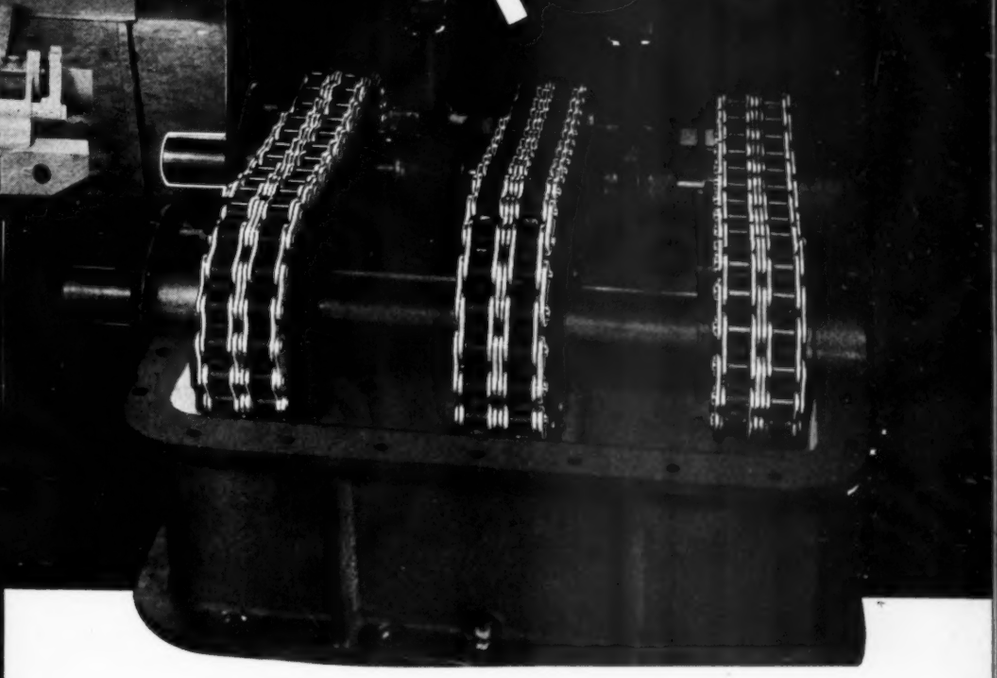

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LINK-BELT *Silverlink* ROLLER CHAINS

Miscellaneous Areas in The Eastern Hemisphere

Several countries yield small quantities of oil or offer prospects of producing commercially

By RALPH H. KING

SEVERAL countries in the Eastern Hemisphere produce oil only in small quantity. No attempt will be made to discuss these countries in order of importance.

Australia

A small quantity of oil is produced at Lakes Entrance in the Gippsland district, Victoria, and thus far only showings have been discovered in other areas. Many test wells have been drilled, the location being selected on the basis of position in recognized basins, as the strata are not exposed at the surface in these basins. Gas has been obtained from some of the wells.

Japan

The portion of Sakhalin Island that is part of Japan is yielding approximately 5000 bbl. of oil per day. Every effort has been made to develop other sources of supply but without much success. As Japan ranks seventh in consumption of petroleum products, this deficiency is sorely felt.

African Continent

Egypt.—Although Egypt produced slightly more than one million bbl. of oil in 1937 the old field at Hurghada has declined and the potential production of the new area at Ras Gharib cannot be determined as yet.

Algeria.—One small pool, Tliouanet, produced in 1937 only 2193 bbl. and no other fields have been found.

Morocco.—The Tselfat and Bon Draa fields were discovered in 1937 and ten producing wells proved an area of 75 acres. Several exploratory wells are being drilled.

Tunisia.—Two test wells were being drilled in 1937.

Madagascar.—Two test wells on the Tsimororo structures have showed thick oil but were not commercially productive.

Ethiopia.—In general the structure does not particularly favor the accumulation of oil, but several faulted areas along the coast offer possibilities and will be tested.

Union of South Africa.—The official government report on the geology of the country virtually condemns it for possible oil production, but some local structures might prove productive if tested.

Europe

Poland.—The production of oil in Poland has declined since 1925 and only a few small fields have been discovered. Deep drilling in old fields has disclosed new producing strata, and some new gas reserves have been found. The most active areas are Jaslo, Borysław, Stanisławow, and the area outside Borysław. The 3530 wells produced in 1937 approximately 3,700,000 bbl. of oil. There were 28 gasoline plants operating in 1937 and they produced about 12,500,000 gal. of gasoline.

Germany.—In 1937 Germany produced about 3,175,000 bbl. of oil. The Neinhagen field produced about 2,428,000 bbl., or more than 75 percent of the total. The Wietze and Oberg fields produced about ten percent and five percent, respectively, of the total. The Zistersdorf field, in what was formerly Austria, produced about 237,500 bbl. in 1937, but this is not included in the total for Germany for that year.

France.—The only field in France that is producing an appreciable quantity of oil is the old Pechelbronn field, and its production for 1937 was less than 500,000 bbl., of which about 200,000 bbl. was produced through shafts. This field is of interest principally because it is the most extensive oil mining project ever developed. The Gabian field produced a small quantity of oil, and two wildcat wells were drilled by the government company.

Czechoslovakia.—Two fields produced approximately 125,000 bbl. of oil in 1937. The old Gbely (Egbell) field, operated by the government, was extended and its production greatly increased thereby. The other field is the Hodonin (Göding) field, operated by the Apollo Company. It produced about one-fourth of the total for the country. Several wildcat wells have been drilled but no additional production obtained.

Hungary.—Prior to 1937 Hungary produced no oil, but last year what appears to be a fairly productive field was found at Budafa-Puszta (Lispe). The field was producing 350 to 400 bbl. of high-grade oil per day at the end of the year.

Another field discovered at about the same time at Bukkszek produces only seven bbl. per day from each of the eight producing wells, but the depth is only 320 feet. The field seems to be unimportant.

Two wells have been drilled for the production of carbon dioxide, and a dry-ice plant has been installed.

Great Britain.—Some oil was produced in England immediately after the war, and a very small amount was obtained from a well in Scotland at about the same time. These indications have encouraged extensive geophysical exploration and test drilling, but thus far only showings have been obtained. Test wells have been drilled in southern England, Scotland, Yorkshire, and especially the Midlands, and additional tests will be drilled until all prospects have been tested.

Esthonia—Although Esthonia produces no oil or gas as such, it has large reserves of oil shale, from which are produced sufficient quantities of fuel oil and gasoline to supply the domestic market and a small export demand.

Albania.—Oil reserves of the Devoli field are approximately 85,000,000 bbl. and more than 40 wells are producing about 2000 bbl. of oil per day. The asphaltic-base crude has a large sulphur content but hydrogenation in Italian refineries produces gasoline of good quality and substantial quantities of lubricating and fuel oils. Some oil has been found at Pathos also.

Greece.—The Bank of Greece has arranged credits to pay for prospecting for oil and gas in Greece, but the prospects do not seem very encouraging.

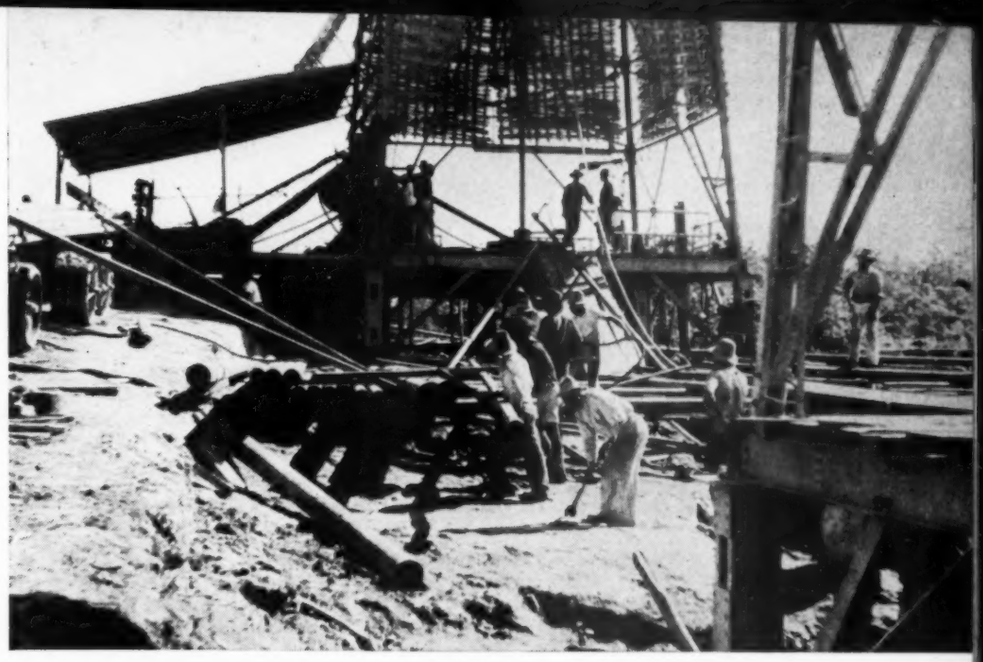
Switzerland.—Rock asphalt deposits are being exploited and test wells have been drilled in a search for oil. Showings were obtained and further exploration will be made.

Italy.—The most recent discovery of oil in Italy was development of an area of about 500 acres in the Vallezza zone at a depth of about 2500 feet. Oil from the Salsomaggiore zone yields 75 to 90 percent gasoline and kerosene.

Netherlands.—A test well near the boundary of Germany obtained a showing of oil in the Zechstein, but further geological and geophysical exploration are necessary.

Sweden.—Natural gas obtained on the island of Oland off the east coast of Sweden contains 1.4 percent helium.

Bulgaria.—In an exploratory well drilled near Varna by the government, a showing of oil was found at a depth of approximately 1000 feet.



Unloading pipe at a well in a Southern Sumatra field

By JOHN F. DODGE
and
WALLACE A. SAWDON

Electrical logging, formation testing, and control of weight and viscosity of drilling fluid are standard practice

Advanced Technique Employed in Developing Fields of Sumatra

A fuel barge on Moesi River

THE oil fields of Sumatra are divided into two principal regions: Northern Sumatra north of Medan and Southern Sumatra centering about Palembang. The two regions are separated by hundreds of miles of unprospected jungle in which geological work is now being done by both Bataafsche Petroleum Maatschappij (Shell) and Nederlandsche Koloniale Petroleum Maatschappij (Socony and Standard Oil Company of New Jersey).

In the northern district oil is produced by B.P.M. and N.K.P.M. Standard is also drilling on a structure near the northern tip of the island. In the southern district Standard currently produces about 40,000 bbl. per day and Shell considerably less, probably nearer 20,000 bbl. per day. In each region production could be greatly increased, but is being restricted to self-imposed quotas to meet market conditions. Production data on both northern and southern areas are given in Table I[1].

All the N.K.P.M. oil is refined at Palembang. All the B.P.M. oil was formerly processed at two refineries, Pangkalan Brandan in the north and Pladjoe in the south, but at present some crude oil is being sent from Pladjoe to the Balikpapan refinery in East Borneo because of the decline of production in Borneo. The oil produced in Sumatra is a light, paraffin-base oil. The average gravity exceeds 40 deg. A.P.I. and wax content is large.

MEDAN AREA

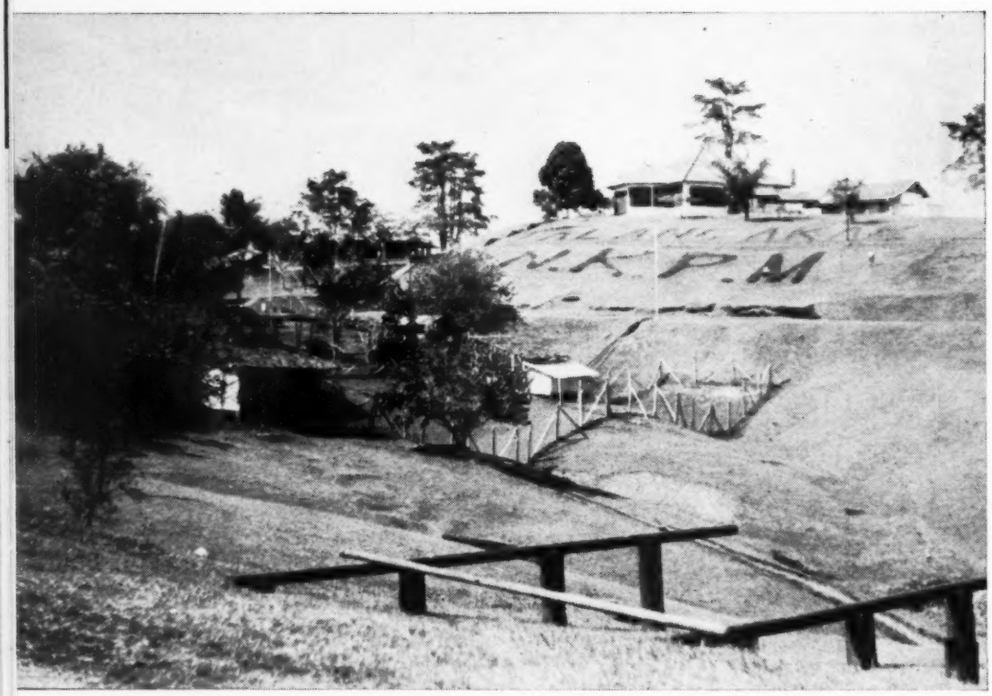
Medan, the principal city of northern Sumatra, is situated near the eastern coast and is about 300 miles from the northern tip of the island. The B.

[1]From A.I.M.E. "Petroleum Development and Technology, 1938."

TABLE I

	South Sumatra	North Sumatra
Age in years to end of 1937	41	52
Total bbl. oil to end of 1937	233,829,304	119,541,895
Total bbl. oil during 1936	26,285,460	5,688,000
Total bbl. oil during 1937	28,118,053	6,777,000
Average daily, December, 1937	33,000	20,516
Average daily, per well, December 1937	74	177
Total gas, million cu. ft., 1936	12,482	6,134
Total gas, million cu. ft., 1937	12,526	7,617
Wells completed to end of 1937	2,695*	747
Completed during 1937	191*	20
Abandoned during 1937	13	3
Temporarily shut down at end of 1937	30	17
Producing oil only at end of 1937	1,267*	116
Producing gas only at end of 1937	2*	----
Total producing at end of 1937	1,378*	133
Average depth in ft.	290–5,400	300–4,140
Average depth to top of producing zone	160–5,200	260–4,100
Flowing wells at end of 1937	97	48
Pumping wells at end of 1937	104	30
Gas-lift wells at end of 1937	244	38

*Includes Java.



The main office of the N.K.P.M. in the producing field of Talang Akar, west of Palembang

P.M. headquarters is situated at Pangkalan Brandan, about 60 miles north of Medan and on a small stream, 12 or 15 miles from the coast. The first production obtained by B.P.M. in northern Sumatra was here, and the refinery, originally a small affair, was built here. At present all production is obtained from other districts and piped to the refinery, which has a capacity of 21,000 bbl. per day. The refined products are pumped to P. Soesoe, about 12 miles northeast, a port where tankers of moderate size can enter in almost any weather.

A very prolific though small field is situated across the river from P. Soesoe and the oil is pumped to P. Brandan for refining, and then back for shipment. The major producing field of the area at present is Rantau about 40 miles north of P. Brandan.

Rantau Field

Rantau is a rather long, narrow anticlinal fold lying at an angle of about 45 deg. to the mountain axis of the island, much as the fields of the west side of the San Joaquin Valley lie with reference to the Coast Range of California. To date about 50 wells have been drilled, all of which produce by natural flow or gas lift, and the field is producing currently about 20,000 bbl. per day. The oil is light amber in color, and the gravity is about 50 deg. A.P.I. Gas/oil ratios are about 600 cu. ft. per barrel. An extension of the field, or possibly another fold on the same axis, lying about ten miles to the southeastward was drilled some years ago but produced gas and only very little oil and at present is almost entirely shut-in.

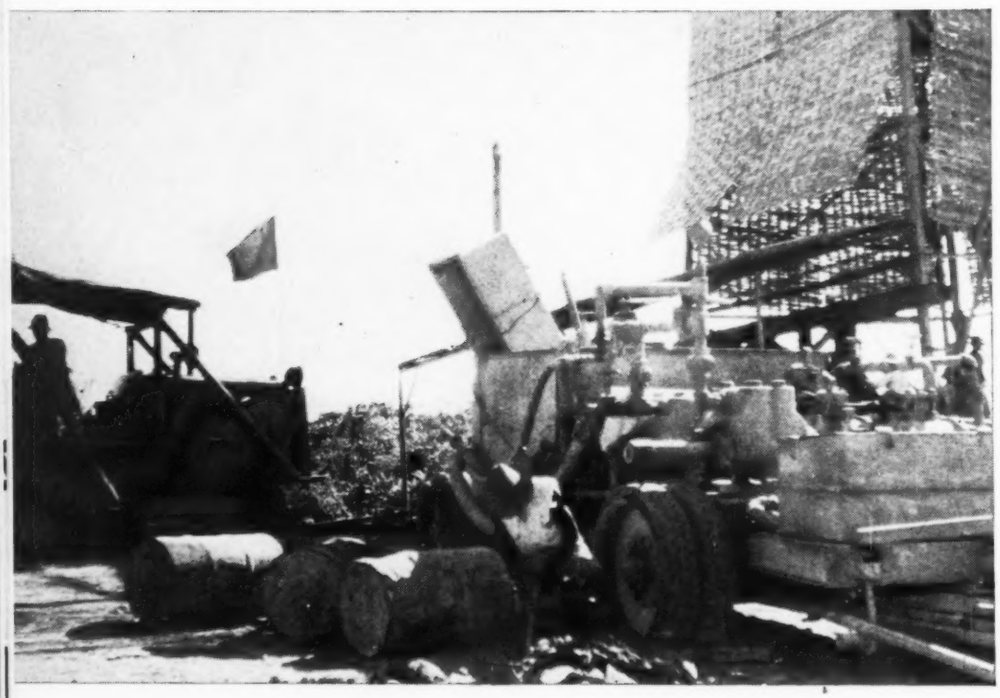
Production is obtained from two groups of sands or zones, which are produced by twin wells commonly drilled from the same location. Depth of the wells ranges from 2500 ft. to 3000 ft., depending upon position on structure. One deep test well, No. 55, while being drilled in December, was having considerable difficulty in fractured shale at a depth exceeding 4800 feet. The shale was not of the heaving shale type and cuttings examined did not swell or soften when placed in water. A later report on this well states that at a depth of 7100 ft. the liner was cemented solid and the well was being tested.

Of the wells drilled, about 20 are now shut-in because of high gas/oil ratios. The two groups of producing zones contain 14 different sands. Some intermediate waters are encountered that cause trouble but the formations are moderately easy to drill. On the deep test cited, fractured shale caused considerable trouble. Rantau is a water-drive field. The flowing pressures are 350 to 500 lb. per sq. in. and are kept balanced throughout the field.

Drilling Practice at Rantau

Three strings of tools are being run on exploitation work at present and drilling practice is exceedingly simple. The wells are started with mud made from the surface clays, which make good mud as drilling proceeds, the upper 2000 ft. penetrated being principally clay almost free from sand. Volcanic activity was extensive in Sumatra in the past, particularly in late Tertiary time, and the clays contain much colloidal material of a bentonitic nature. Drag bits are used with a mud of 80 or 85 lb. per cu. foot. Whenever any weight is needed, barytes of spe-

(Continued on Page 129)



Rigging up equipment for a cementing job on a well in one of the South Sumatra fields near Palembang

(Continued from Page 126)

cific gravity 4.3 is used and is said to be satisfactory.

At present no mechanical coring is being done at Rantau but all wells are electrically logged and formation testers using a conical rat-hole packer provide data on production prospects.

The mud weight and viscosity are tested at frequent intervals, the weight being measured by bucket and scales and the viscosity by an efflux viscosimeter, similar to the Marsh Funnel except that a brass cylinder about 1¾ in. in diameter and 12 or 15 in. long is used. A tube about 3/32 in. in diameter is screwed into the bottom and the tube filled with mud that has been carefully screened. The time of efflux of 250 ml. is taken as the viscosity number of the mud.

Good equipment is used by the administration. The company is standardizing on 275-lb. steam equipment and 7¼-in. by 14-in. by 18-in. pumps. The tendency is to use Diesel-driven rigs for isolated tests.

Northwest of Rantau the numerous old producing fields are to be drilled deeper because the shallow productive zones have become water-flooded. Casing includes a 9⅝-in. surface string, 6⅝-in. water string, and 4¾-in. liner. A still smaller casing program is planned that will include 8⅝-in. surface string, 5½-in. water string, and 4-in. flush joint or 3½-in. liner.

Wildcat Drilling

In addition to the three rotary rigs active in the Rantau field, the B.P.M. Pangkalan Brandan Administration is using two others to drill test wells some distance from Medan. One of these is on the Tjoenda Block slightly more than four miles northwest of Lho Seumawe, about 150 miles from the Rantau field. This well, last reported drilling at a depth of 5000 ft., is being drilled with a modern Diesel rig. The company has under concession several properties in that general territory.

An exploratory well was being drilled by B.P.M. on a structure about 12 miles north and west of P. Brandan and when visited (December 5) was drilling at a depth of 4700 feet. Native mud of 75 lb. per cu. ft. was used and a supply of barytes was available for use if high-pressure gas was encountered. It was thought that this well would be a failure as the depth recommended by the geological department had been reached without encouraging indications.

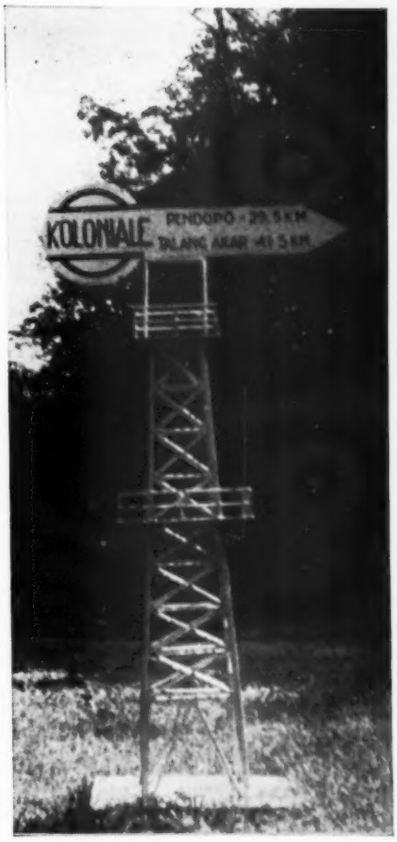
Other Company Operations

At Pasé the Nederlandsche Koloniale Petroleum Maatschappij has an old area 16 miles west and south of Lho Seumawe. This structure is situated in a rolling virgin jungle at an elevation of 100 ft. and the climate is cool and comfortable.

Two rotaries are in use and a general expansion program is under way. Only nine wells have been drilled in five years. These have a depth of 2000 ft. and produce 140 to 220 bbl. of 50-deg. A.P.I. oil per day from a zone 80 to 250 ft. thick. Water and sand troubles, however, are prevalent. A pipe line is to be laid from the field to Lho Seumawe Bay in the near future.

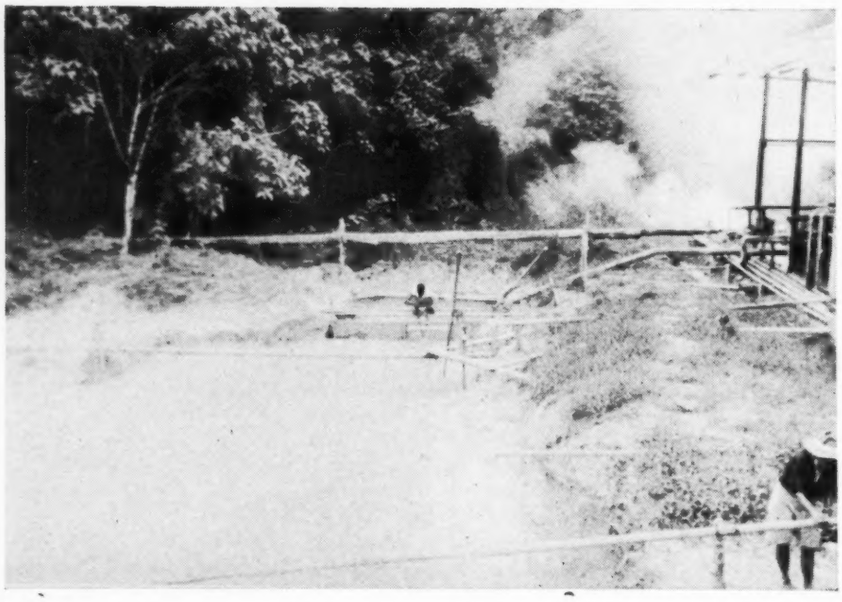
Casing consists of 11¾-in. surface string, 8⅝-in. water string, and 6⅝-in. liner. The company favors the smaller casing program for the future and will use it if it proves feasible.

Nederlandsche Pacific Petroleum Maatschappij is core-drilling the large Rokan Block lying on the east coast north of Rokan River and approximately midway between Medan and Palembang. It is planned to make Medan the geological headquarters for



Pointing the way to the famous Pendopo field, 18 miles away. Talang Akar is eight miles farther

Map showing location of producing fields of Sumatra



Mud pit adjacent to drilling well where drilling mud is made from surface clays. Northern Sumatra

operations in the Netherland East Indies. A heavy rig recently used to drill a test well in western Java has been moved to the Rokan area for a deep test. This Block lies in a very low, swampy district. The company has constructed some modern, shallow-draft house-boats as living accommodations for the field parties and intends to provide living quarters for the wives of the staff members at an early date.

SOUTHERN SUMATRA

The fields in southern Sumatra are centered around Palembang, a town of about 100,000 persons, which is situated at the junction of three navigable rivers, and at a distance of 30 miles by river from the eastern coast. Communication with Medan by plane once a week is the only direct communication, as hundreds of miles of trackless jungle separate the two centers. The plane makes one stop, at Pakanboroe, about 150 miles north of Palembang, from which point an auto road runs to the port of Padang on the west coast.

As mentioned previously, both Shell and Standard have headquarters on the opposite side of the river Moesi from Palembang and are reached by ferry and auto. Each company's office is at its refinery, the location of which is governed by the accessibility to water transportation. Tankers of moderate size come up the river and dock at the refinery piers. Refined oil is shipped to Batavia, Soerabaya, and to a marine transfer station near Singapore, as well as to Calcutta, Bombay, and Madras. At present crude oil is being shipped by Shell to the refinery at Balikpapan in Borneo.

In the Palembang district the oil pools lie in parallel ridges trending northwest-southeast at the north but more nearly east-west toward the south. The folds are narrow domal areas on closed anticlines, locally asymmetrical, the steeper dips being on the western side toward the mountains. The producing strata are sand lenses in the Middle Palembang formation of Lower Pliocene age and Lower Palembang and Goemai shales of Miocene age. (See generalized cross-section accompanying the introductory article on the "Oilfields of India, Burma, and the East Indies.") As in all the islands of the East Indies, the greater production comes from the Lower Miocene. In Table 2 is given a stratigraphic column typical of South Sumatra.

N.K.P.M. Operations

The headquarters for all Nederlandsche Koloniale Petroleum Maatschappij operations in the Netherland East Indies are at Soengei Gerong. Here the company has a large new oil city situated ten miles from Palembang and beyond Pladjoe, the B.P.M. headquarters. There is a distinctly American atmosphere about the place. The camp and buildings cover a large area adjacent to the refinery, which has a capacity of 45,000 bbl. per day.

The principal producing properties of N.K.P.M. or Koloniale, as it is called, are those at Pendopo, about three hours by car from Palembang. The Pendopo anticline is a spur fold much like the structures in northern Sumatra, but somewhat larger, and production is obtained at depths less than 3000 feet. The wells are drilled

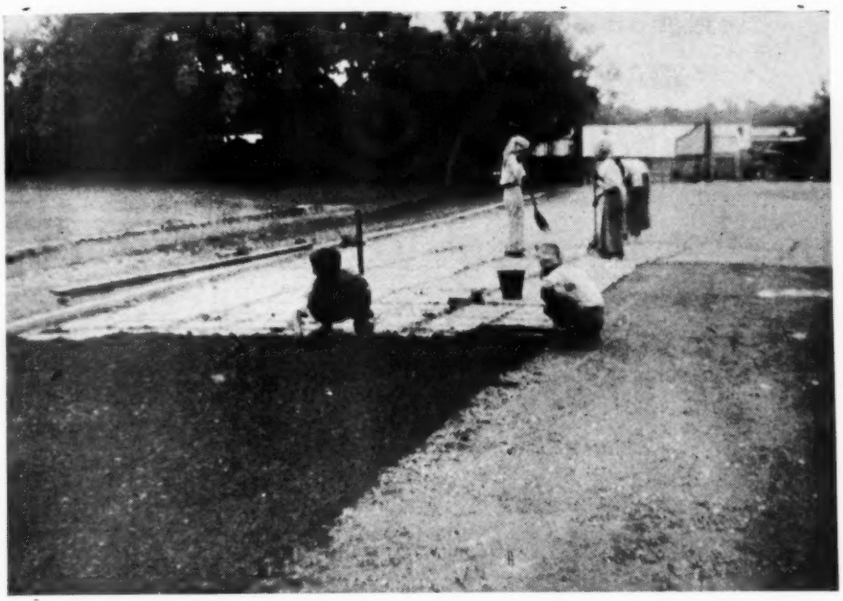
(Continued on Page 133)

TABLE 2
Stratigraphic Column—South Sumatra

Period	*Formation*	*General Description*
Pliocene	Upper Palembang	White to gray tuffs interbedded lignite seams. Poorly stratified clays gray to blue in color. No oil. Thickness 3900-5500 ft.
	Middle Palembang	Blue to chocolate-brown clays, marls, and sandy shales. Beds of lignite. Tuffs. Coal deposits mined by Government. Oil at Moeara Enim. Thickness 1200-2000 ft.
Miocene	Lower Palembang	Blue to black clays, marls, thin-bedded sandstones, sandy shales — impure limestone beds — Globigerine marls and glauconitic sands. Beds of tuffs. Oil in Northern Palembang. Thickness 4000-6000 ft.
	Goemai (Telisa shales in Djambi)	Dark and blue-black shales and interbedded thin limestones, also sandstone beds separated by thin shale members. Chalky orbitoid limestone in S. W. Palembang. Shales petroliferous at surface. Hard shales. Oil production throughout. Thickness 6000 ft.
Oligocene		Orbitoid limestones from Batoe Rodja. Clay marls and marly sandstones north of Moeara Doea.
Eocene		Clay shales and coal. Upper Rawas. Coal-bearing breccia and conglomerates near Moeara Duwa and Upper Rawas.

(From "Petroleum in Dutch East Indies" by Fred B. Ely, A.I.M.E. Petroleum Development and Technology, 1931.)

Local color in Northern Sumatra



Laying roads in Northern Sumatra. Crushed rock and asphalt (brought from Borneo) is placed—a pebble at a time—by hand

(Continued from Page 130)

by rotary tools in 14 to 20 days. Surface casing is set at depths of 600 to 900 feet and the water string at 2500 to 2700 feet. The wells are drilled on a spacing of 650 ft. by 825 ft. and are all flowing or on gas lift. Current potential exceeds 40,000 bbl. per day. The oil is 36 deg. A.P.I. and lighter.

Drilling is extremely simple. The wells are started with surface clay, cut up in the pit with a hydraulic gun, and make much mud in the first 1500 ft., as the surface strata contain several bentonite layers. Mud weighing 75 or 80 lb. is used and a supply of barytes is available for use if necessary, but little or no weight material is in use in exploitation drilling. The personnel is familiar with the use of an Aquagel-water mixture for drilling-in.

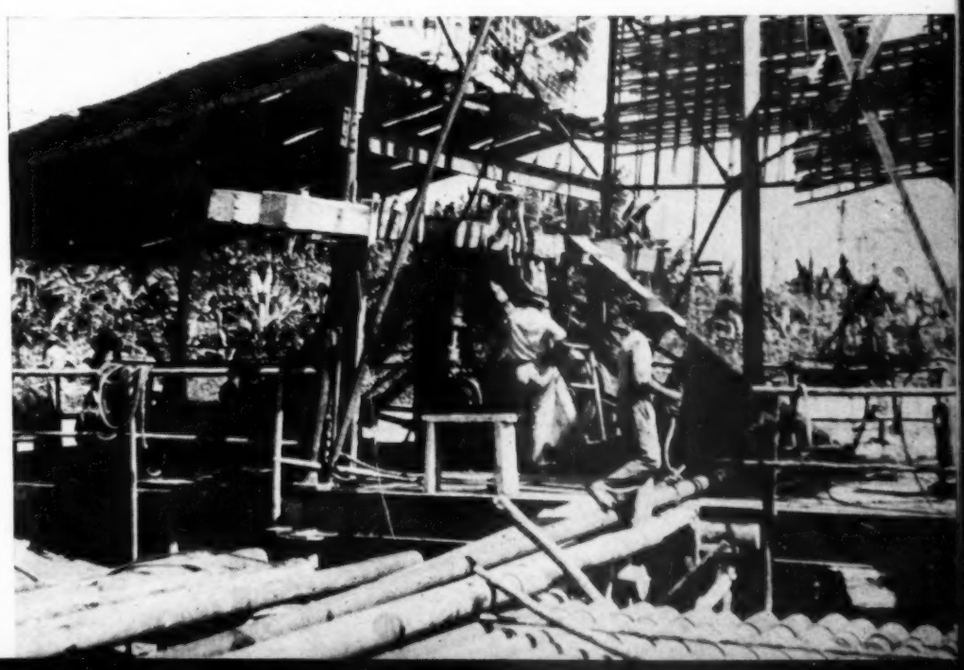
The Koloniale owns about ten other areas that are producing or in some stage of exploration. These are scattered through the territory in which the B.P.M. properties are situated and extended to Taloek, north of Djambi. The company has six rigs drilling in Sumatra, three on wildcat wells. Bottom water appears to be encroaching in some areas and its elimination requires considerable attention at the present time.

B.P.M. in Southern Sumatra

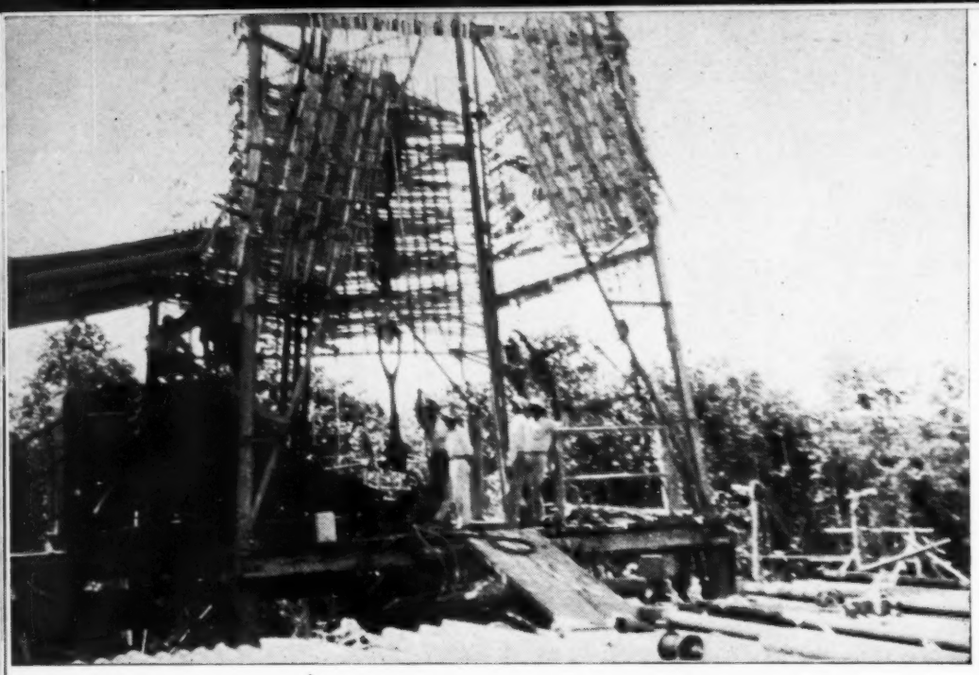
The Pladjoe Administration in south Sumatra is the largest and most active administration being operated by the B.P.M. The company's headquarters at Pladjoe is the usual extensive city of dwellings, offices, shops, warehouse, and docks. Moesi River affords good anchorage for large tankers and even European liners. The B.P.M. refinery here has a capacity of 30,000 bbl. per day.

B.P.M. production in southern Sumatra is widely scattered, extending over 100 miles northward from Djambi to some small structures about 125 miles southeast of Palembang. Total current production slightly exceeds 20,000 bbl. per day but could be greatly increased.

On this administration there are approximately 500 wells, most of which are flowing high-gravity oil. The depths range from 2500 to 6000 feet. There are 11 rotary rigs active in the territory and 26 areas either are producing or being considered for exploration.



A drilling operation in Southern Sumatra



Rigging up in Southern Sumatra

The main producing and drilling areas are in Soeban Djerigi District, which includes:

Goenoeng Kemla	new area	2 rotaries	6000 ft.
Limau	new area	1 rotary	5000 ft.
Soengei Taham	old area	1 rotary	2500 ft.
Talong Djimar	old area	3 rigs	5000 ft.
Sengkoean	old area	1 rotary	2500 ft.
Loentar	old area	1 rotary	3000 ft.
Rambang	wildcat test, rotary rig		

Several drilling crews are engaged in these areas, in approximately the ratios shown, consideration being given to the fact that some are tearing-down or rigging-up on various locations.

During the last year a 9000-ft. dry test was drilled in this district but was abandoned because of mechanical trouble. Formations are easy to drill and more four-way drag bits are being used than any other type. Cementing operations are also easily conducted, only two failures being recorded in the last three years. The district has more than 300 miles of good B.P.M. roads in addition to government roads, the former being constructed and maintained by American equipment.

Government Reserve

Around Djambi is the N.I.A.M. Government Reserve, which is operated by B.P.M. on a partnership arrangement. The active areas here are:

Badjoebang	1 rotary	2500 to 3300 ft.
Kenali Assam	1 rotary	3000 to 3600 ft.
Meroeo Senami	wildcat test, rotary rig	
Tempino	2500 ft.; intermediate water problems	

As in northern Sumatra the weight material is barytes. Believe it or not, there are no emulsion problems in Sumatra. Waxing of tubing and sucker rods causes only slight trouble in the few pumping wells.

Petroleum Equipment Exports Increase

ACCORDING to a semi-annual review by the Machinery Division of the U. S. Department of Commerce, American manufacturers of petroleum equipment continue to ship their products abroad in record quantities.

Value of exports of such equipment from the United States during the first six months of 1938 reached the record total of $21,008,415, a 21 percent gain gain over the record January-June shipments last year valued at $16,453,-988, and 39 percent above the previous peak first-half-year figure of $15,093,-620 in 1930.

The first six month foreign sales of drilling apparatus amounted to $12,-374,417, approximately 50 percent greater than the corresponding 1937 shipments valued at $8,300,973, and more than double the previous peak half-year exports aggregating $5,342,-409 in 1930.

Venezuela was our leading foreign market during the first half of 1938 as well as 1937, taking shipments valued at $3,471,723 and $1,866,720 in these two periods, respectively. Colombia ranked second through June of this year, the exports of drilling equipment to that country totaling $1,544,808, more than five times the comparable 1937 figure of $281,929.

Trinidad and Tobago was our third largest foreign customer during the period under review, spending $1,240,-378 compared with $811,678 in the first half of 1937. Equipment valued at $382,310 and $259,019 was shipped to Ceylon and New Zealand, respectively, whereas no exports were reported to those markets in the same period of 1937.

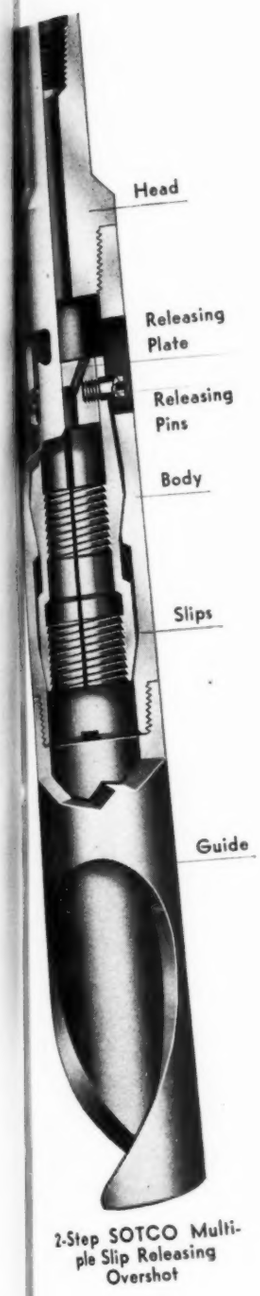
Other noteworthy increases included Iran, to which American exporters sent drilling equipment valued at $384,361, compared with $138,864 in January-June, 1937; Egypt, $253,971 as against $25,027; Australia, $106,168 compared with $1,486; Iraq, $97,601 as against $10,359; Burma, $123,562 as compared with none during the same period of 1937; British Malaya, $252,-423 as against $77,071; Saudi Arabia, $198,336 compared with $85,605; Peru, $157,498 as compared with $104,805; Argentina, $536,243 compared with $357,173; France, $179,-865 compared with $30,186; Czechoslovakia, $101,659, none the first six months of 1937, and Canada, $756,961 compared with $667,159. The Netherlands Indies dropped from second to fourth place in this trade, taking shipments valued at $923,043 in January-June of this year compared with $1,-565,359 in the first half of 1937.

Foreign sales of all other petroleum machinery in January-June, 1938 totaled $8,633,998, six percent more than the $8,153,015 exported in the comparable period of last year, and slightly less than the first half year peak figure of $9,751,198 in 1930. A feature of this trade during 1938 has been the gain in the shipments to the Netherland West and East Indies.

American exports of petroleum equipment, other than drilling equipment, to the Netherland West Indies were valued at $2,659,732 in January-June of this year, compared with $670,224 a year ago, and the corresponding figures for the Netherlands East Indies were $1,087,955 against $215,515. In contrast, shipments to our leading market a year ago, Soviet Russia, dropped from $1,959,680 to $220,640. Another outstanding gain was recorded in the shipments to Iran, to $928,199 from $116,919 a year ago.

Other important increases included Iraq, $286,718 compared with $182 a year ago; Colombia, $257,079 compared with $228,143; Canada, $223,-564 compared with $193,465; Rumania, $217,366 as against $168,885; France, $141,873 compared with $9,-295; and Egypt, $70,730 this year, $13,106 a year ago. Although less than those of last year, shipments to some other important markets were as follows: Other Asia (Afghanistan, Nepal, Bhutan, and Portuguese Timor, Macao, Goa, Damao, and Diu), $634,995 compared with $1,079,761 a year ago; Trinidad and Tobago, $374,455 compared with $569,539; Argentina, $128,729 this year, $453,875 a year ago, and Venezuela, $572,103, compared with $747,507.

Fishing at its Best
with SOTCO "DEEP ZONE" ROTARY FISHING TOOLS



2-Step SOTCO Multiple Slip Releasing Overshot

SOTCO offers the industry a complete line of specialized "deep zone" rotary fishing tools, serviceable at any depth and under every conceivable condition, especially designed to facilitate recoveries and reduce hazards. These tools are strong in construction, fool-proof in design, and simple in operation. They are now being used in all the principal oil fields of the world, and wherever available for immediate use, serious fishing jobs are prevented and risks of stuck pipe and "washing over" jobs are eliminated.

SOTCO MULTIPLE SLIP RIGHT HAND RELEASING OVERSHOT (SOCKET) 2-STEP and 3-STEP TYPES. These tools have been developed from the original SOTCO Single Step Releasing Socket, which is still manufactured. They provide more efficient, safer fishing, covering all present-day demands. Both types are short and convenient, being readily placed in the side of the derrick or transferred from well to well. They do not require extra pipe in operation, as it is unnecessary to go under the collar or tool joint to get a hold. The 2-Step Socket (shown at left) will catch tool joints and pipe in one operation, while the 3-Step Socket (shown at right) will catch tool joints, upset, and pipe in one operation, without changing slips or making extra runs. The slips have separate actuating tapers and teeth, taper travel being the same; which permits catching two or three sizes at the same time. This feature eliminates one of the greatest hazards of fishing by allowing a full grip to be obtained on the fish, where only a very short hold ordinarily would be possible. These Sockets are designed for Packoff and Mil's on all sizes—Packoff body being separate feature, and may or may not be used when running the tool. Standard guides are shown in accompanying illustrations. However, guides can be furnished in any desired type or bowl.

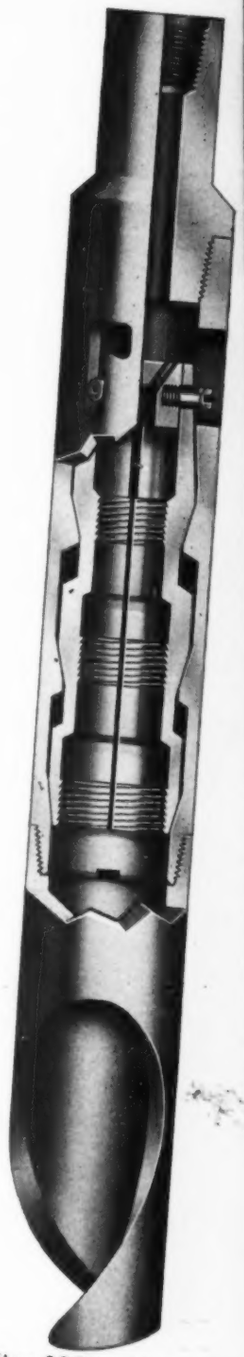
The SOTCO *catalog illustrating and describing the complete line of* SOTCO *fishing tools, will be mailed on request*

WASH-OVER HYDRAULIC WALL HOOK for washing over, cutting, inside shooting and shaking loose from the wall.

HYDRAULIC KNUCKLE (dog leg) for carrying any type fishing tool around a curve and out into a cavity.

PLAIN WALL HOOK: Has tool joint box for screwing into Hydraulic Knuckle. A tool which can be swung over to describe a large circle after pipe lost in "cave in"—slips do not take hold until pipe is in line with hole.

ADJUSTABLE GRAB for picking up any piece of metal, tool or equipment broken off or dropped in the hole, or stuck in the wall formation.



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Oil Production in Assam

Active geophysical exploration and the drilling of numerous deep tests give rise to hope for additional important discoveries

By JOHN F. DODGE and WALLACE A. SAWDON

Assam Oil Company's Well No. 348, the well having the largest production in the Digboi field

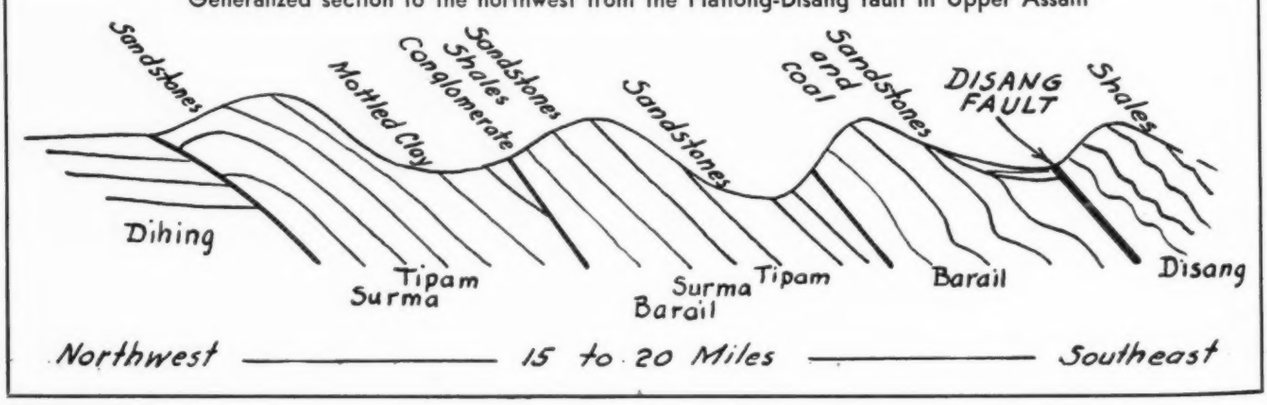
ALTHOUGH the Digboi field yields virtually all the oil produced in Assam, the many seepages along the Haflong-Disang fault and north and east of Surma Valley have for many years offered a constant hope of other important discoveries. Geological prospecting has been intensive over the entire region and many wells have been drilled without success. At the present time geophysical exploration is being done in some areas and comparatively deep test wells are being drilled both in wildcat territory and in areas where shallow wells have given definite indications of possible production.

The stratigraphic column as worked out and tested by the Burmah Oil Company in Assam consists of the divisions and sub-divisions given in Table I.

According to Lepper[1] "It will be seen from the accompanying map that oil seepages are numerous in Upper Assam along the hills south of the Brahmaputra alluvium. The important oilfield of Digboi is in this belt. The next important series of oil seepages is in the southern part of the North Cachar Hills, along the southern edge of the Shillong Plateau, and in the anticlines on the south side of the Surma Valley. . . . .

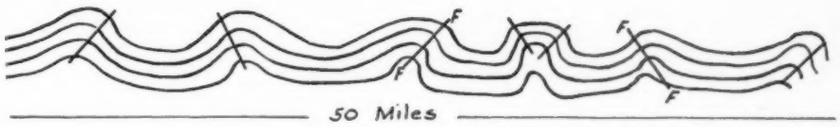
[1] "An Outline of the Geology of the Oil-Bearing Regions of the Chindwin-Irrawaddy Valley of Burma, and of Assam-Arakan," by G. W. Lepper, World Petroleum Congress, London, England, July 19-25, 1933.

Generalized section to the northwest from the Haflong-Disang fault in Upper Assam

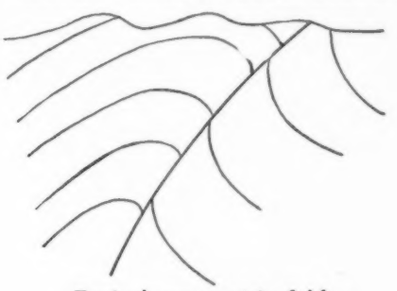


"No oil is found in the Eocene Jaintia Series or in the Disang Series. There are no oil indications certainly referable to the Barails south of Badarpur, either in Assam or in the Chittagong-Arakan region, but there are many oil-shows and some large seepages in the Barails of the hills northeast of the Surma Valley. The small oilfield of Badarpur (in the Surma Valley) has given production for 18 years from sands of the Renji Stage. Much salt water is associated with this oil. North of the Haflong-Disang fault, oil seepages occur in several of the narrow-faulted outcrops of the Barails, especially in Upper Assam, where oil-shows are commonly found in close association with the coal-bearing rocks of the Coal Measure sub-Series. There is no separation of 'oil measures' and 'coal measures' for, although most of the oil-shows are well below the thickest of the seams, oil-sands often occur in between the thinner seams, and petroliferous coal seams have been recorded. . . .

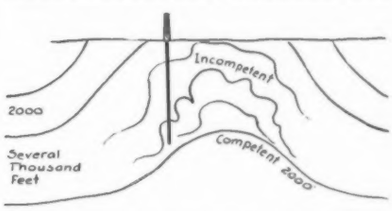
"In the Surma Valley, oil- and gas-shows occur in all the sub-divisions of the Surma Series, and are found in several of the anticlines as well as along the southern margin of the Shillong Plateau. A few oil-shows occur in the Surma beds of the south-western part of the Naga Hills, but none has been recorded from the Surma Series outcrops further north-east. Tipam oil-shows are restricted to a limited area in Upper Assam; they occur fairly numerously along the Jaipur-Digboi line of folding but are limited to the



Generalized section of Surma Valley



Typical asymmetric fold



Generalized indication of subsurface at Masimpur
(Note: No sketch is to scale)

TABLE I

Mio-Pliocene

Dihing Series (maximum thickness 5000 feet)

Probable unconformity

Miocene

Tipam Series (maximum thickness 12,000 feet)
- Num Rong Khu stage
- Girujan clay stage
- Tipam sandstone stage

Surma Series (maximum thickness 13,000 feet)
- Boka-Bil stage
- Bhuban stage

Widespread and important unconformity

Oligocene to Eocene

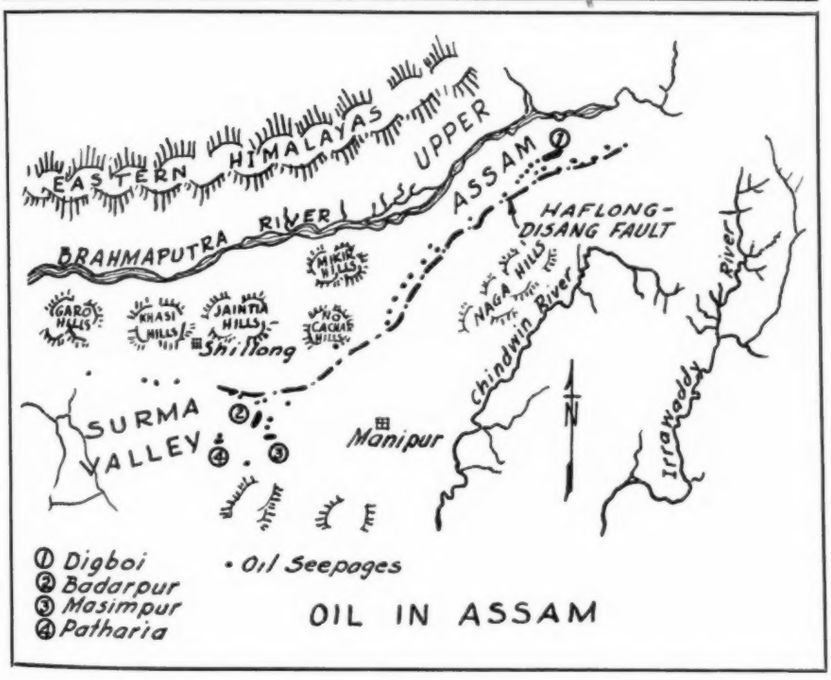
Barail Series (maximum thickness 15,000 feet)

Renji stage	upper	Upper Assam only		
	lower	Tikak Parbat stage	Coal Measure sub-Series	
Jenam stage	upper			
	lower	Baragolai stage		
Laisong stage	upper			
	lower	Naogaon stage	Eocene	

Jaintai Series (3000 feet) (north of Haflong-Disang fault, in Central Assam Range)
- Kopili alternations stage
- Sylhet limestone stage

Disang Series (thickness exceeds 10,000 feet) (southeast of Haflong-Disang fault)

(Probably equivalent in its upper part to the Jaintai Series, and may be Cretaceous in its lower part)



Oil fields of Assam. For general location see map showing producing fields of Burma and Assam

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A roomy, comfortable staff house at Digboi

Tipam Sandstone and basal Girujan Clay. In this area the Tipam Sandstone contains a greater proportion of argillaceous material, although the general facies does not suggest a marine environment.

"The oil-shows are almost all associated either with anticlinal crests or anticlinal faults or with the monoclinal flexure along the southern edge of the Shillong Plateau. . . .

"The occurrence in Middle Tertiary time of a period of uplift and erosion probably led to the formation of local depressions in which later oil-forming sediments may have been concentrated."

DIGBOI FIELD

The Digboi field is operated by the Assam Oil Company, the controlling interest in which is held by the Burmah Oil Company. Situated in the Lakhimpur district of Upper Assam, the structure is sharply folded, the northern flank is overturned and faulted, and the closure is great. The fold pitches sharply and is greatly compressed to the west but has a long gentle pitch to the east. There is probably no interruption of the southerly dip for several miles. It would thus seem that conditions are favorable for the migration of oil from the north and east and to a less extent from the south. The productive zones occur in the Tertiary coal measures.

The productive area is approximately three and one-half miles in length and three-fourths mile in width. Production has increased steadily since the field was first drilled in 1888 and there is geological justification for expectation of greater production. Correlation is exceedingly difficult, however, the Digboi field resembling Yenangyaung in this respect.

The oil from Digboi is a paraffin-base crude containing solid paraffins of a high melting point; as it also contains considerable quantities of naphtha and gas, the slightest loss of any of the lighter hydrocarbons leads to the immediate deposition of paraffin.[2] As producing wells therefore must be cleaned frequently, pumping is somewhat expensive. Rotary drilling is preferred because considerable trouble from caving sands is experienced when cable tools are used.

At present this field produces 4000 to 5000 bbl. per day from approximately 200 wells. The oil is dark green in color and its gravity is 30 to 40 deg. A.P.I. A total of 383 wells has been drilled to depths ranging from 500 to 5600 feet. A few of the deeper wells flow as much as 250 bbl. per day; in other wells gas-lift and pumping powers are used where possible. Considerable gas accompanies the oil but pressures are low. The shallower wells produce a few to 60 bbl. per day. Recent decline in production has been due to water.

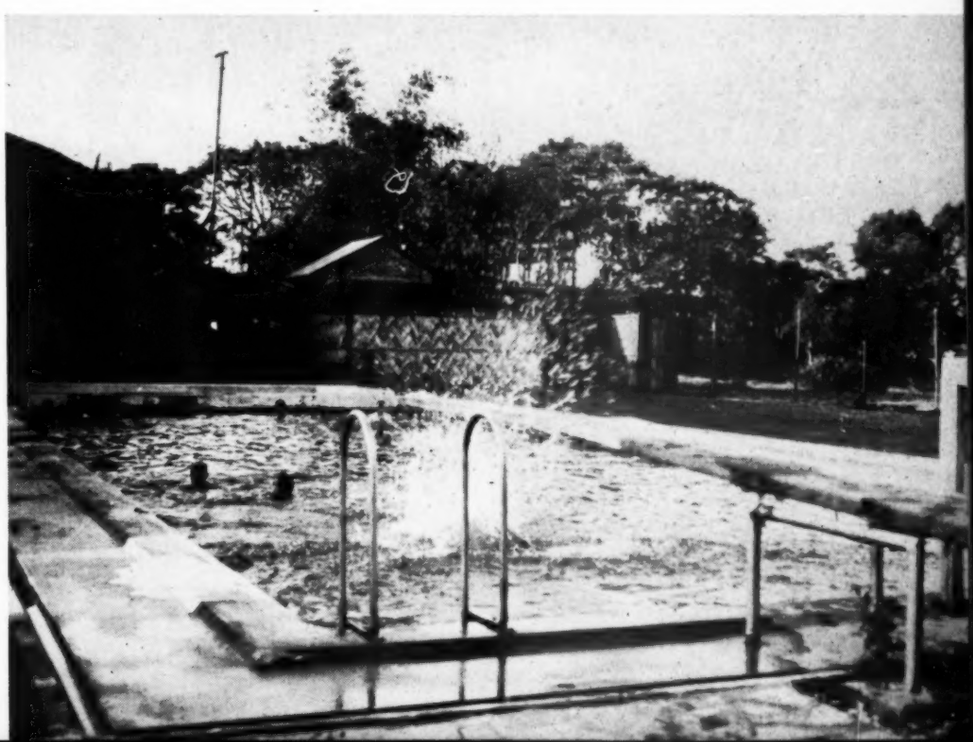
The upper formations consist of sandstones, shales, and shells. The producing zones are oil sands and shales, and the deeper wells penetrate as much as 2000 ft. of producing formation. Rock bits are used in drilling the 9½-in. hole below the water string but good time is made in the upper formations by using certain types of fishtail bits.

The casing in deep wells consists of a 10¾-in. water string and a 5¾-in. liner, the latter set in 9½-in. hole. In very shallow wells the practice is to set either a 6⅝-in. or 8⅝-in. combination string.

In cementing these combination strings the company has been setting a cementing basket at the cementing point and pumping the cement down a string of tubing run outside the casing. This has seemingly not proved very effective as many of the shallow wells are cutting a large percentage of water.

In the deep wells penetrating thick producing zones that are making water, there seems to be some doubt as to the point of water entry. Because of the seriousness of this condition, the

[2]Sir E. Pasco: Mem. Geol. Survey of India (1914) 40, Pt. 2, 298.



The Assam Oil Company at Digboi provides such modern conveniences as a swimming pool, tennis courts, and golf links

operators plan to cement the 5¾-in. liner solid and then gun-perforate by stages. If a water zone is encountered it can be cemented-off by use of a cement retainer. Control of the condition of the mud has aided materially the drilling of the deeper wells.

Five rotary rigs are operating in the Digboi field, one on reconditioning work. One well being reconditioned is scheduled to be deepened as a 9½-in. hole to test formations to a depth of 7000 or 8000 feet.

Steam is used for power in all operations. Standard steel derricks and modern rig equipment of standard design are employed on most of the wells. Equipment recently introduced includes some 12-in. by 12-in. twin engines.

Refining

Adjacent to the south side of the Digboi field is the Assam Oil Company's 5000-bbl. refinery. The crude from the Digboi field is similar to that produced at Yenangyaung in Burma but contains a greater percentage of solid paraffins and has a larger content of asphaltum. Gasoline and kerosene are the main products refined and these are transported by pipe line to the company's packaging plant at Tinsukia Junction, where they are put into cans for distribution in northern India by rail and water transportation.

Other Areas in Assam

Three 64-ft. semi-portable cable-tool rigs have been prepared for the purpose of drilling three wells on the Namdang structure, which lies 12 miles northeast of the Digboi field on the south side of Brahmaputra River. This is a proved area but the wells are small.

In that general area there are several known structures that may have possibilities for production, and further to the northeast is Namchick, north of the river, which was proved several years ago. In the foothills of the Naga Hills and in the flat country of Upper Assam there are several possible structures and it is contemplated that in 1939 four outside tests will be conducted under jurisdiction of the Digboi headquarters.

Although the Badarpur field operated by the Burmah Oil Company in the eastern part of Surma Valley did not prove as good as hoped, more than 60 wells were drilled in this area. These wells, however, are now abandoned. This anticline is a small dome having a steep, faulted eastern flank. The developed area was about a mile long and one-quarter mile wide. The decline in production was rapid and the wells produced a great amount of water. The oil was inferior to the Burma crudes and was used largely for fuel. Test wells drilled to depths exceeding 3000 ft. yielded oil, but had the usual rapid decline in production.

At Masimpur, also in the eastern part of Surma Valley, a few wells have been drilled and some production obtained by the Burmah Oil Company. The anticline is a large closed structure. There are many gas and oil seepages. As at Badarpur, caving formations and water cause considerable trouble while drilling.

In the Masimpur test area drilling has been suspended temporarily but core drilling for seismograph exploration is in progress to select a location for another deep test. A test well at Masimpur recently was drilled to a depth of 6600 ft. but at that depth the well was thought to be off the structure. The Burmah Oil Company, however, has been active in the Masimpur district since 1916 and has expended more than £150,000 already. Present operations would indicate that the company has not lost confidence in the possibility of oil in that area.

Test wells at Patharia have not proved successful but extensive geophysical work is being done in this particular area and throughout the territory in which the Badarpur and Masimpur fields lie. Petroleum deposits exist along the southern edges of the Khasi and Jainta Hills and considerable prospecting has been done near the Shillong Plateau.

North and northwest of Badarpur are oil seepages on a monocline along the southern boundary of the Shillong Plateau. Farther east and north are oil showings on fault structures of the Naga Hills. The thrust planes are steeply inclined and the usual distance between thrusts is only three or four miles. Several wells have been drilled but oil has not been found in commercial quantities. Farther northeast is a long structure known as the Jaipur, at the northeastern extremity of which is the Digboi anticline.

The Petroleum Industry in France

EFFORTS in France to obtain some degree of self-sufficiency as regards motor fuel supplies were begun soon after the World War and have been directed mainly toward the encouragement of refining of imported crude oils, the development of her limited oil resources at Pechelbronn and oil shale deposits at Autun, and toward the greater use of alcohol. The annual consumption of petroleum products in France is now nearing seven million tons and her production of crude oil is only 78,000 tons, or slightly more than one percent of her requirements, with but little prospect to increase this output. For use in motor fuels there is an important output of benzol from coke oven gases and there has been recently a small output of synthetic gasoline.

Great progress has been made in recent years in building-up the refining capacity in France and in reducing the imports of refined products. In 1928 French oil refining was limited to two refineries, one at Courchelettes for imported crude oil and the other at Merkwiller for the distillation of domestic crude from Pechelbronn. The total capacity of these refineries was about 200,000 tons per annum. The laws of March, 1928, for the establishment of refineries and the subsequent decrees giving them customs protection and licenses for a period of 20 years afforded an assurance of stability for the necessary investment in new plants. The rapid increase in refinery capacity to about seven million tons of crude in 1937 is the result of this legislation and today France produces almost all her requirements of refined petroleum products from imported crude. Because of this change it is estimated that the annual trade balance of France was improved by about $20,000,000 whereas the expenditures in new refineries was about $80,000,000.

The principal output of crude oil is from the oil field at Pechelbronn, north of Strasbourg. The oil deposit consists of a sandstone bed a few feet thick, interstratified in limestones of Triassic age, which occur at a depth of 2953 to 3281 feet. This bed was explored first by drill holes and then by shafts and drifts. All the oil is extracted from the wells by pumping and the output per well is very small. From the shafts there is a grid of drifts and crosscuts in the sandstone bed and at points 33 ft. apart are sumps to collect the oil. In each sump there is a vertical pipe with valve connected to a main pipe line into which the oil is sucked when the valve is open. At the shafts there is a pump to force the oil to the surface. It is estimated that by drill holes about one-third of the oil from a given area is recovered whereas by shafts and drifts the recovery is two-thirds.

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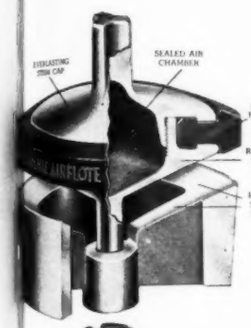

The New MacClatchie Airflote Pump Valve

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Hundreds of satisfied users report smoother performance at low cost with these pistons. MacClatchie Wearever Pistons are the only pistons that can be made as good as new by replacing the rubbers. The steel center spool is completely protected from liner contact at all times, and both liner and piston are protected from wear.

Wearever Piston Rod

Made of ball race steel, heat treated and ground, Wearever Piston Rods save pump breakage and give better rod, piston and liner wear. This rod gives superior service under all conditions at a price only slightly higher than inferior makes. They are made for any size pump and in any taper desired. Strongly recommended is the MacClatchie Special Taper Rod which has just the right amount of taper to remain tight under extreme pressure yet can be readily removed.

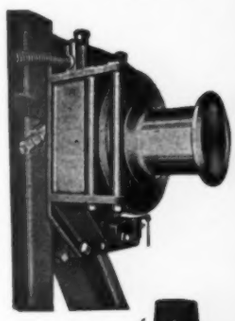
"Money-Saver" Pump Liner

Manufactured from high grade seamless steel tubing, these liners are uniformly heat treated and ground to a mirror finish and have no soft spots to hasten breakdown or cause pitting. Removable glands and rubbers can be used over and over again and only the liner itself need be replaced when worn. MacClatchie Liners reduce shipping costs to any domestic or foreign field in two ways—first, lighter original weight, and second, long wearing replaceable glands which are used over and over again and save freight on reorders. In addition to reduced shipping costs you save also in long trouble-free wearing life of the liner! MacClatchie "Money-Saver" Pump Liners outwear any others regardless of price.

Hydro-Seal Plug Valve

MacClatchie Hydro-Seal Plug Valves are now equipped with the new "Lubricheck," the only mechanical means of regreasing plug valves under pressure. "Lubricheck" closes off the entire area subject to gas or fluid leakage and permits complete removal of the Lube Screw and insertion of a new grease stick while the valve is in operation. MacClatchie Hydro-Seals are available in a complete range of sizes with screw, flange or union ends, hand or gear operated, and in working pressures of from 250 to 3000 pounds.

Gearomatic Cathead



Double the power at half the line shaft speed is secured with the MacClatchie Gearomatic Cathead. Geared two to one, this is the only cathead which is geared to reduce the terrific impact when breaking tool joints. Greatly reducing jerks, jarring and strain on the drawworks, this cathead breaks the largest joints with a smooth powerful pull. Because of its slow steady revolution, it saves catlines and eliminates the danger of injuring any member of the crew. Ideal for fast line shafts as it pulls with just half the speed of ordinary catheads.

"The Modern Cathead for Modern Drilling"

MacClatchie Wall Scraper

Wherever smoother operation, greater safety and less wear and tear on equipment are desired, the MacClatchie Wall Scraper is the best scraper for today's deep well operations. Three cutters give greater strength, insure true hole, eliminate vibration and torsional strain on drill pipe. The MacClatchie Wall Scraper is the *only* scraper which gives positive notification on the rig floor when cutters are expanded in the hole. Rugged construction insures stabilized cutting, full expansion, full fluid flow for scraping, greater body strength and unusually large reaming capacity. Use of the MacClatchie Wall Scraper in reconditioning the hole, redrilling and in gravel packing will assure a more thorough job in faster time than ever before possible.

Write for descriptive catalog on these and other MacClatchie Products

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Excessive Pressure Complicates Drilling of Punjab Fields

Prolific flows of water at high pressure, even at shallow depths, must be combatted

By JOHN F. DODGE and WALLACE A. SAWDON

ALL production from Punjab Province of India comes from the old Khaur field and the more recently developed Dhulian field. Both pools are situated in the most northerly part of Punjab near the boundary of the North West Frontier Province and lie approximately 60 miles by road southwest of Rawalpindi, a military town that serves as a base for military forces operating in the North West Frontier Province.

At Rawalpindi are the general offices and refinery of the Attock Oil Company, Ltd., which holds the concession on which all present commercial production has been obtained. Test wells have been drilled in much of the area shown on the accompanying map but no other commercial production has been found. More exploratory work will probably be done in the immediate vicinity of Rawalpindi within the next year.

At Jhatla, some distance south of Dhulian field, Attock owns some property on which the Whitehall Petroleum Company once drilled a well to a depth of approximately 6000 feet. This well entered the top of the lime and drilling was then stopped, as no production was expected in the lime. Now knowing that the limestone is the productive formation in the Dhulian field, Attock will test the area in the near future.

Attock Oil Company, Burmah Oil Company, and Indo-Burma Petroleum Company have holdings at Dera Ismail Khan but have announced no definte plans for testing. Indo-Burma also has various prospecting licenses in North West Frontier Province and at the present time is drilling a cable-tool test at Chorlakin, 90 miles north and east of Khaur. At a depth of 2600 ft. some minor showings have been reported.

A concession of approximately 200,000 acres lying northwest of the Dhulian field has recently been acquired by Burmah Oil Company, and a party of geologists has been working there for the last few months. This concession is situated in the Punjab and North West Frontier Provinces.

Refining and Pipe Line Operations

The present Attock refinery at Rawalpindi has a capacity of only 1500 bbl. per day. Owing to the great production now available from the new Dhulian field, a new refinery is being started. All products are manufactured and marketed by the Burmah Oil Company, which distributes throughout northern Punjab and North West Frontier Province. Gasoline sells at 70 to 75 cents per Imperial gal., the price including a tax of about 23 cents.

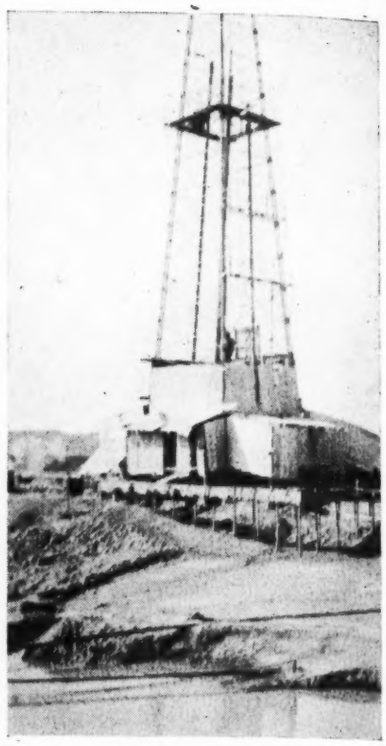
Crude is transported from the fields to Rawalpindi through a 6-in. line. The old line from Khaur to the refinery is a coupled line; a new 6-in. line from Dhulian to Khaur is electric welded.

Three wells are already completed and a fourth is nearly finished in the Dhulian field. One storage tank has been erected at the Dhulian end of the pipe line and two tanks having a capacity of 1,000,000 Imperial gal. (nearly 30,000 bbl. each) at Khaur. A pumping station pumps the crude from Dhulian to Khaur, a distance of ten miles, and another boosts it and the production of the Khaur field to Rawalpindi. Although the distance from Khaur to the refinery is nearly 60 miles, the country is flat so the one station is easily able to move the oil required by the refinery.

KHAUR FIELD

Attock Oil Company has drilled approximately 300 wells in the Khaur field, some of which have produced oil from depths as shallow as 100 feet. The oil is a high-gravity, paraffin base crude and is now being produced by about 150 wells, some of which yield only a few gallons per day. Production reached a peak exceeding 500,000 bbl. per year in 1929 but has since declined to less than 300 bbl. per day. Two cable-tool rigs are drilling and one deep test is being drilled by rotary rig, this being a joint test of the Attock Oil Company and the Burmah Oil Company. A late report, however, states that this deep test, which encountered very high pressures, is now being abandoned.

In the Khaur field,[1] relatively high pressures were found, even at very shallow depths. The pressure in cable-tool-drilled wells could not be controlled by water at a depth of 2000 ft., and at a depth of 2800 ft. the pressure in rotary-drilled wells could not be restrained by 90-lb. mud. At depths exceeding 3200 ft. the shale in open hole would cave badly upon release of pressure.



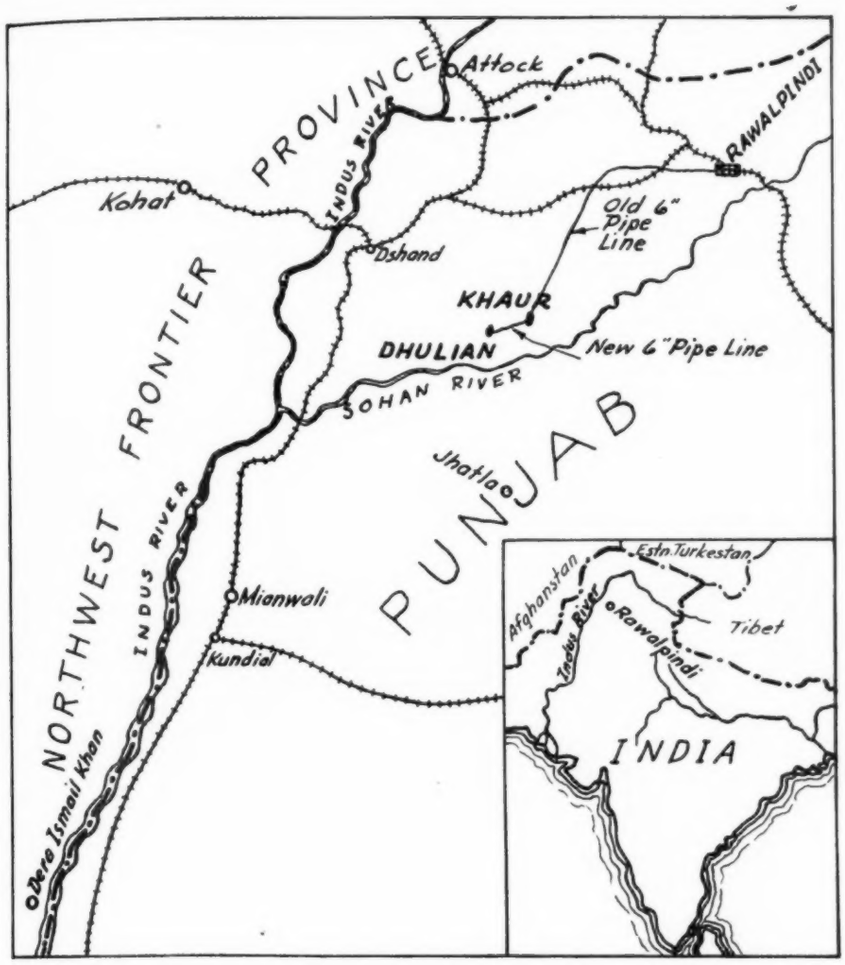
Third producing well in the Dhulian field. Initial production was 2000 bbl. per day

Because the formation pressure greatly increased below 3500 ft. the common practice on all wells drilled below this depth was to install high-pressure fittings provided with emergency valves. Where casing was cemented above the high-pressure sand, oil was sometimes produced through the drill pipe.

Drilling mud weighing as much as 160 lb. per cu. ft. was made by the addition of barytes but was robbed of its collodial properties by the salinity of the water encountered during drilling. Whenever rotation of the drill pipe ceased, the barytes and mud solids would settle to the bottom of the hole and freeze the drill pipe.

Pressure drilling in this field was first used in 1932 but was used then only for drilling-in. As only one bit was required for the operation no snubbing-in equipment was provided. The drill pipe was 2⅞-in., 3½-in., or

[1]Data on early development of the Khaur field is obtained from a paper entitled "Drilling Against High Pressures in the Khaur Field, Punjab" by C. E. Keep, M.Sc., and H. L. Ward, Attock Oil Company, Ltd., presented before the Institution of Petroleum Technologists (now The Institute of Petroleum) in London.



Map showing location of Khaur and Dhulian fields and areas in which exploratory work is being done

5-in. flush joint and was equipped with one or more back-pressure valves. The string was tested to 2500 lb. per sq. in. when the bit reached bottom, and after drilling started the pressure at the beaned discharge lines was kept at approximately 500 pounds. When the gas zone was reached, the driller increased the control pressure by means of smaller beans until the pressures were balanced and the hole would neither make nor take fluid.

The bit was raised when the final drilling depth was reached but the full pressure was still held on the well. The well was generally brought-in through the annular space between the drill pipe and casing by opening one of the beaned lines and stopping the pumps.

The control pressure was determined by the amount required to prevent fluid entering the hole from the formation. At depths of 4800 to 5300 ft. the required pressure was found to be 2000 to 2300 lb. per sq. in. when 85- to 95-lb. mud was used. In the first deep test made in 1934, the well alternately extracted water from the drilling fluid or added to it from the formation as the control pressure was raised or lowered.

Present Deep-Drilling Methods

Although the greatest production has come from the 3800-ft. sand in the Khaur field, several deep wells have been drilled. Snubbing equipment has been used in these operations and because of the pressures encountered it has been necessary to snub 5-in. drill pipe 2000 to 3000 ft. into and out of the hole at each round trip.

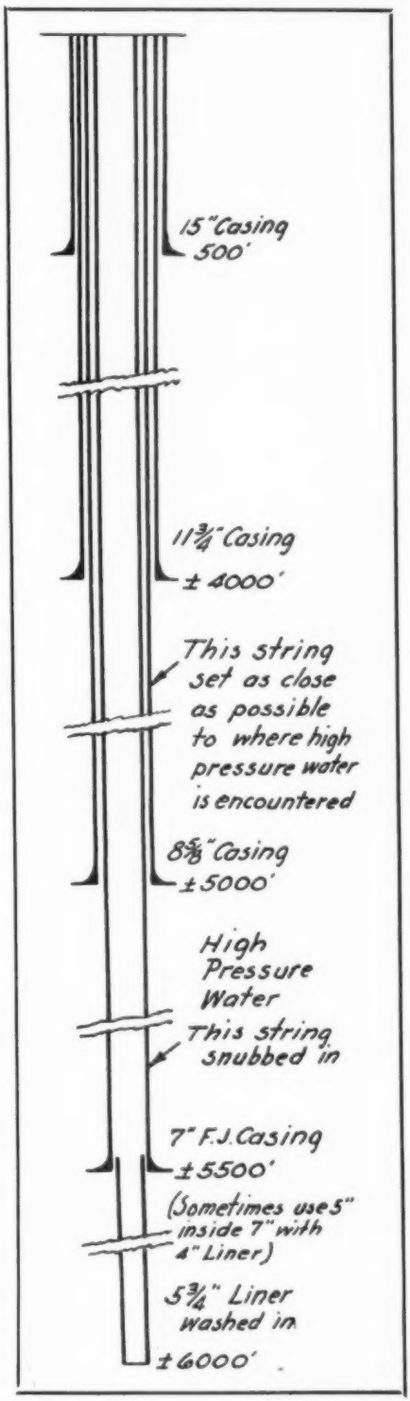
The deep wells in the Khaur field have been drilled mainly by special type bits and rock bits, the coring being done by hard-formation core bits. The general casing program is illustrated in Fig. 1, which shows 7-in. flush-joint casing cemented above the producing zone in a completed well. In some wells, however, it has been necessary to run and cement a 5-in. flush-joint string within the 7-in. and then wash-in 4-in. liner instead of 5¾-inch.

The 8⅝-in. casing is cemented just above the high-pressure water sand, which is usually found at a depth slightly below 5000 feet. Further drilling is done under pressure in a closed system and when the 7-in. flush-joint casing is run it must be snubbed-in. This string is then cemented and the rest of the well is also drilled under pressure.

The surface equipment used while drilling under pressure is indicated in Fig. 2. A hydraulic ram on the derrick floor supplies hydraulic force to actuate rubber rams in the two control

(Continued on Page 154)

Fig. 1. Typical casing program now used for deep wells in Khaur field



FOR HIGH PRESSURE CONTROL OPERATIONS

SHAFFER "SAFETY FIRST" CONTROL EQUIPMENT eliminates the dangers of costly blow-outs—facilitates operations—and provides economical means for handling all high-perssure formations. Shaffer Hook-Ups require the minimum amount of vertical space in the cellar; and are readily converted into Production Hook-Ups without any necessity for killing the well.

1 Shaffer Cellar Control Gates positively close and hold against the highest pressures. The Flange Type, at right, is tested to 4,000 pounds per square inch.

2 The casing is screwed into heavy bosses in the gate body. Shaffer "Screw Type" Cellar Control Gates are available up to 6,000 pound test. Rams are made to fit any size pipe that will pass through the bore of the gate; also for complete shut-off when the drill pipe is out of the hole.

3 Gates can be closed either mechanically or manually with the Shaffer Pelton Wheel-Hand Wheel Combination.

4 This is the Shaffer Full Opening Spool Type Landing Head with flangeless base plate to which the surface string is welded. The Tubing Head is flanged to the upper landing head.

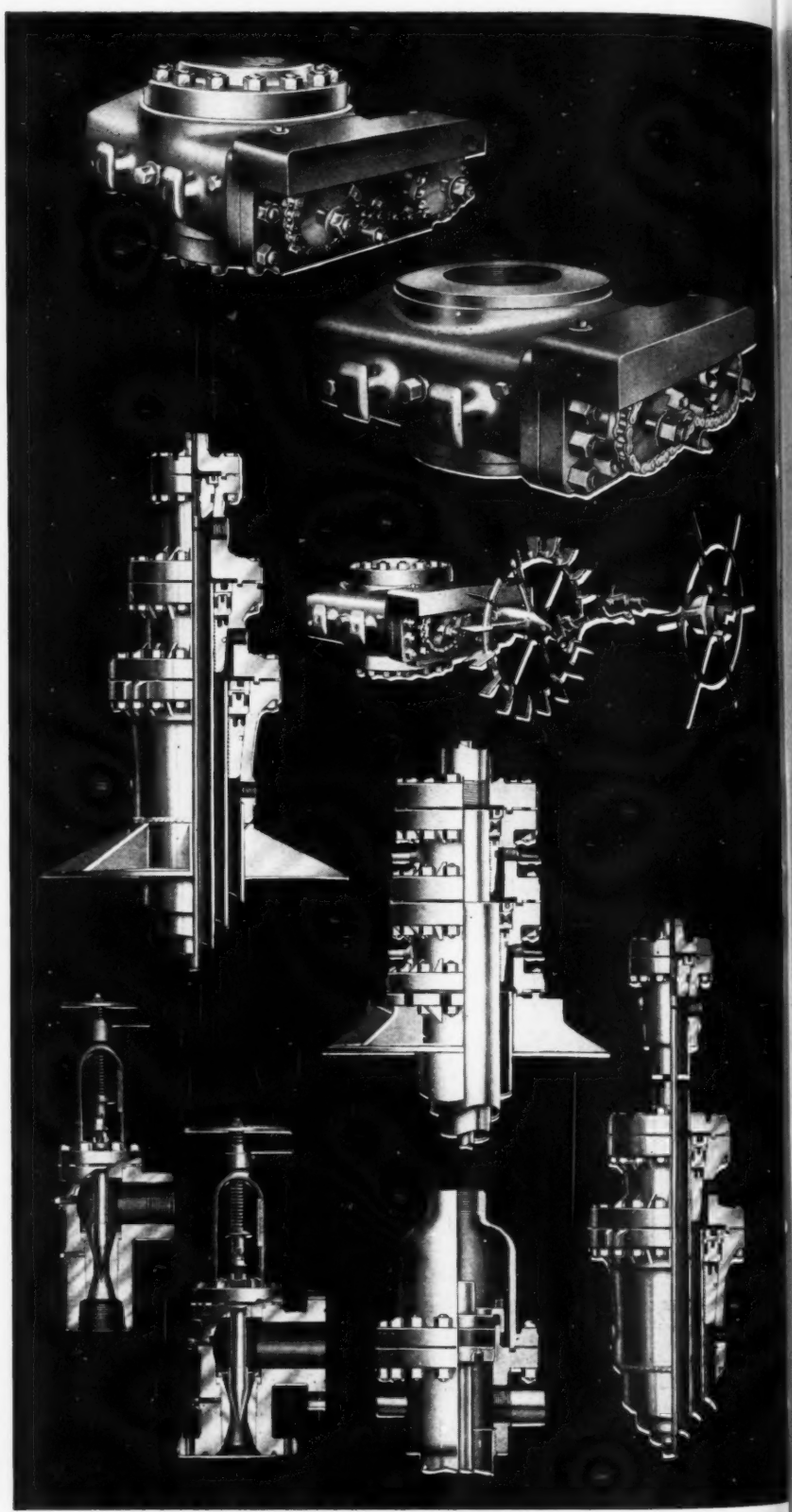
5 Shaffer "Class B" Spool Type Landing Heads (up to 6,000 pound test) permit each string to be landed at any desired point, without "letting go" measuring or re-threading; each string is supported on its own flange, and its own set of slips, with no accumulation of weight by subsequent strings of casing or tubing; and each string is packed off against high pressure, with provision made for gas outlet, mud line or overflow.

6 There is no interference with drilling operations when a Shaffer Full Opening Spool Type Landing Head is used. Shown here welded to casing with Tubing head on riser nipple.

7 Extreme accuracy, both of pressure regulation and rate of flow, is provided by Shaffer Adjustable Flow Beans, shown here with Conical Tip. Furnished also with Micro Tip to permit uniform accuracy with each turn of hand wheel.

8 Shaffer Adjustable Flow Beans, with A.P.I. Ring Joint Flanges, enable production hook-ups to be built quickly and easily, and they further eliminate danger from poorly cut and leaky threads.

9 Another successful Shaffer Product is the Warren Control Head used to pack off drill pipe, casing or tubing, or for making connections for a shut-off or to a production hook-up with the well under control.



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HIGH PRESSURE DRILLING AND CONTROL EQUIPMENT

Described in detail on Pages 1863 to 1898 of the 1938 COMPOSITE CATALOG

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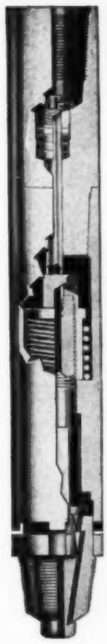
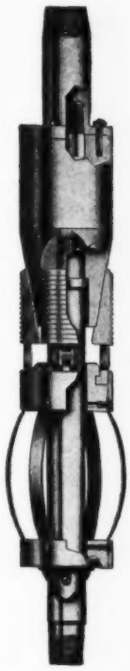
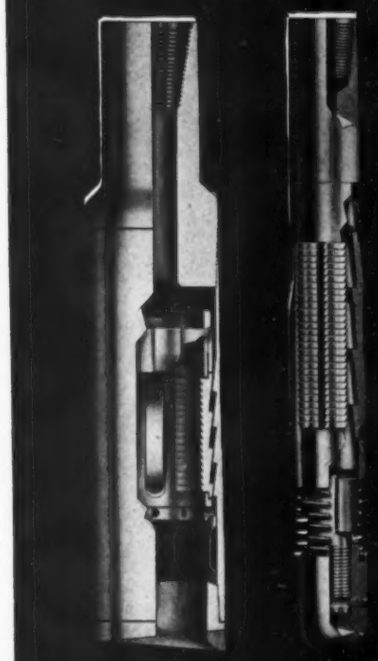
EACH SHAFFER TOOL illustrated on this page has been proved by years of use to be completely dependable. All of them are particularly suited for operation in fields far from the source of supply, due to their positive, low-cost performance, as well as to their simple, sturdy construction which permits them to be readily assembled or taken apart.



Shaffer Expanding Pin Tap



Shaffer Improved Water Test Packer

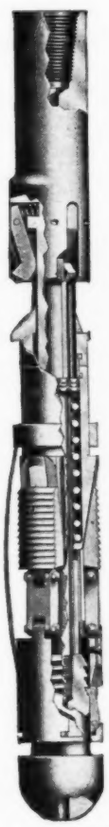


Shaffer T. & T. Rotary Releasing Sockets and Spears are unexcelled for left hand work.

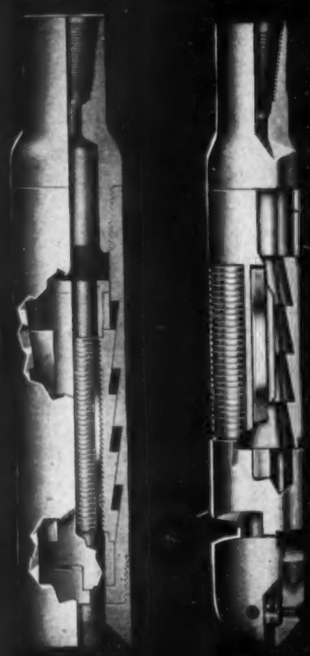
Detailed descriptions of the complete Shaffer Line are in your Composite Catalog, or in the Shaffer Catalog which is free to any oil man who requests it.

Shaffer Liner Hanger

Shaffer Double Bowl Rotary Releasing Socket



Shaffer Inside Casing Cutter



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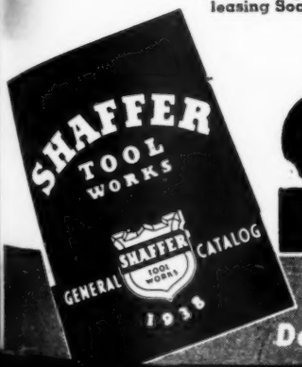


SHAFFER

FISHING TOOLS THAT EXCEL

Described in detail on Pages 1863 to 1898 of the 1938 COMPOSITE CATALOG

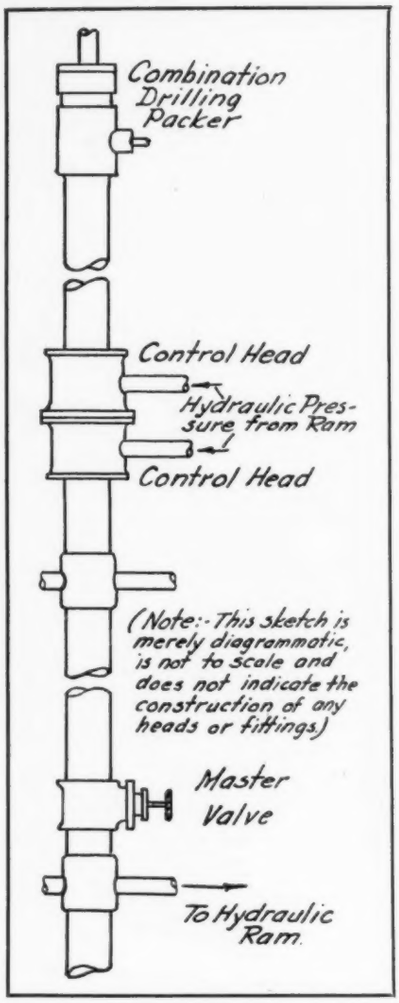

Combination Drilling Packer
Control Head
Hydraulic Pressure from Ram
Control Head
(Note:- This sketch is merely diagrammatic, is not to scale and does not indicate the construction of any heads or fittings.)
Master Valve
To Hydraulic Ram

Fig. 2. Surface equipment used in drilling deep wells under pressure in Khaur field

(Continued from Page 151)

heads. These control heads are connected by a flange of special design that permits the heads to be readily joined without danger. When pressure trouble is encountered, the master valve is closed after the bit has been snubbed through it, and a valve on a line leading from one side of the tee below the master valve to the hydraulic ram is opened. The well pressure is then applied to the hydraulic ram, which is also weighted with a 500-lb. weight. The force delivered by the ram causes the rubbers in the control heads to close around the drill pipe.

The weight of the mud fluid used in pressure drilling averages about 74 lb. per cu. foot. The excess shale carried upward by the returns is removed by shale traps. (Fig. 3.) Four of these traps, two vertical and two horizontal, are installed at each well so that one of each can be in service at all times. The traps are made of 16-ft. lengths of 11¾-in. casing reinforced by 12-in. collars shrunk on the 11¾-in. pipe.

The mud from the well enters the trap through a 3-in. connection and the liquid portion is allowed to leave through the slots provided in the 3-in. pipe, which extends almost the entire length of the trap. The shale cannot pass through the slots and is retained in the chamber. When the trap contains enough accumulated shale it is taken from service and the shale is removed by opening the water line into the chamber and flushing through the outlet provided at the opposite end.

The present joint Burmah Oil Company and Attock Oil Company deep test, when drilling at a depth of 5800 ft., was drilling with 5-in. drill pipe through 9-in. flush-joint casing under pressures to 4000 lb. per sq. inch. High-pressure water flows cause most of the difficulty and the closed-circulation system of pressure drilling is being used to overcome them. Progress is slow because of the pressures encountered and the drill stem is sometimes stuck.

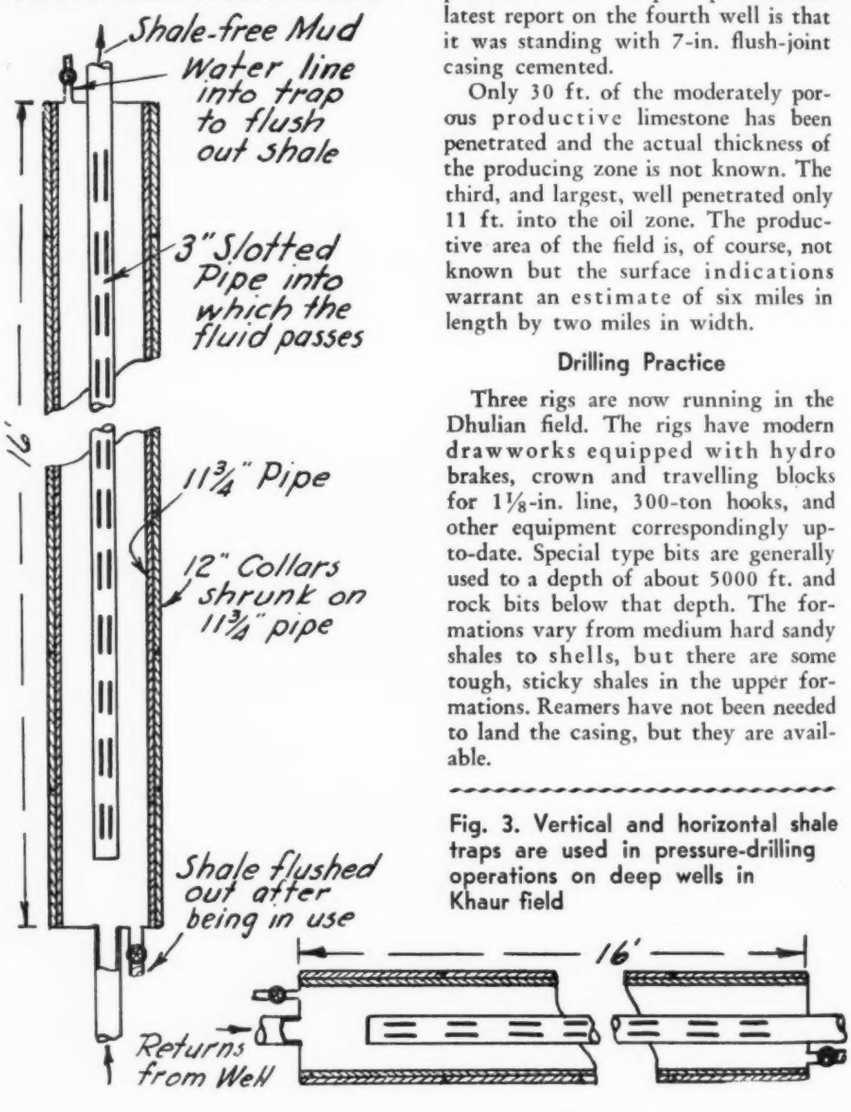

Shale-free Mud
Water line into trap to flush out shale
3" Slotted Pipe into which the fluid passes
16'
11¾" Pipe
12" Collars shrunk on 11¾" pipe
Shale flushed out after being in use
16'
Returns from Well

Fig. 3. Vertical and horizontal shale traps are used in pressure-drilling operations on deep wells in Khaur field

DHULIAN FIELD

Interest is now centered on the Dhulian field, which lies about ten miles southwest of Khaur. This field, prospected and drilled by Attock Oil Company, Ltd., has been tested by ten or twelve wells. These older wells have been abandoned. It is only recently that wells have been completed in the 7700-ft. zone, from which prolific production can be expected. The oil here comes from a limestone, is greenish black in color, and has a gravity of 40 to 45 deg. A.P.I. The discovery well, completed in midyear 1937, had an initial production of 600 bbl. per day.

The two wells first completed are flowing approximately 1200 bbl. of clean oil per day, which is about all the oil the company can handle at the present time. Both wells are beaned-back and the pressure at the well head is kept at 650 lb. per sq. inch. A third well recently completed had an initial production of 2000 bbl. per day through a ½-in. bean at a flowing pressure of 900 lb. per sq. inch. The latest report on the fourth well is that it was standing with 7-in. flush-joint casing cemented.

Only 30 ft. of the moderately porous productive limestone has been penetrated and the actual thickness of the producing zone is not known. The third, and largest, well penetrated only 11 ft. into the oil zone. The productive area of the field is, of course, not known but the surface indications warrant an estimate of six miles in length by two miles in width.

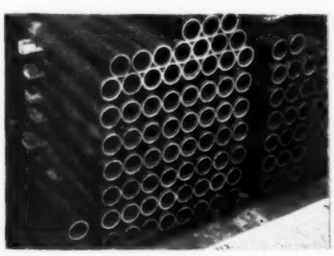
Drilling Practice

Three rigs are now running in the Dhulian field. The rigs have modern drawworks equipped with hydro brakes, crown and travelling blocks for 1⅛-in. line, 300-ton hooks, and other equipment correspondingly up-to-date. Special type bits are generally used to a depth of about 5000 ft. and rock bits below that depth. The formations vary from medium hard sandy shales to shells, but there are some tough, sticky shales in the upper formations. Reamers have not been needed to land the casing, but they are available.

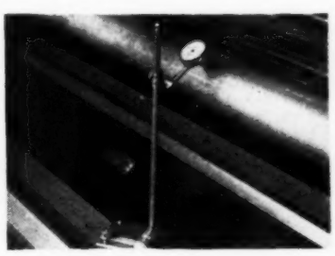
STARTING LIFE for A LINER'S "OVERCOAT," the PUMP JACKET

THERE IS NO ECONOMICAL SUBSTITUTE FOR QUALITY

To the average user of deep well plunger pumps the jacket is merely a piece of tubing that holds a series of liners. To Axelson, however, pump jackets are important—so important that they are constructed of cold rolled material—requiring twenty-four manufacturing and inspection operations between the raw stock and finished jackets. ¶ After every manufacturing operation on any Axelson product a check is made by the machine operator to verify accuracy. These inspections are then further checked by regular shop inspectors. ¶ This care and attention to every detail of pump fabrication is one of the reasons why Axelson pumps have a world-wide reputation for long life and economical production.

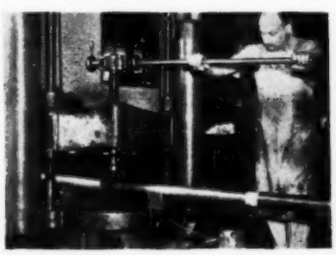


1. Special cold rolled steel tubing of various sizes for Axelson jackets is stored in the tubing warehouse.

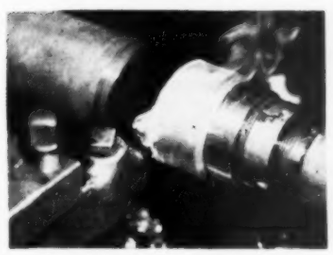


3. Axelson jacket material must meet definite specifications for straightness. This is checked with dial indicators.

2. All tubing is rolled to definite specifications and is carefully inspected immediately upon arrival.



4. Where misalignment is disclosed the tubing is straightened to conform to exact tolerances allowed.



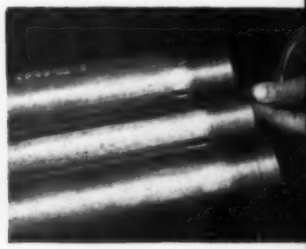
5. After straightness has been verified, jacket material is placed in Axelson lathes where ends are chamfered.

6. After chamfering the jacket ends, they are lathe turned to the proper size preparatory to threading.

7. Axelson chasers chase the thread on both ends of jacket. Threads are gaged before removing from machine.

8. As an added precaution, threads are again checked by an inspector after the lathe operator's check.

9. Next, a plug gage is passed through the entire length of each jacket, checking roundness and size of bore.



10. Inspectors verify that every Axelson jacket has been previously cut and finished to correct lengths and tolerances.

11. After all manufacturing and inspection operations, each jacket is painted and stenciled with its part number.

12. After painting and stenciling, threaded ends of each jacket are coated with a special rust-preventive solution.

13. Finished jackets are carefully stored in Axelson stock rooms, for shipment or to be made up as complete pumps.

AXELSON

DEEP WELL PLUNGER PUMPS

SUCKER RODS

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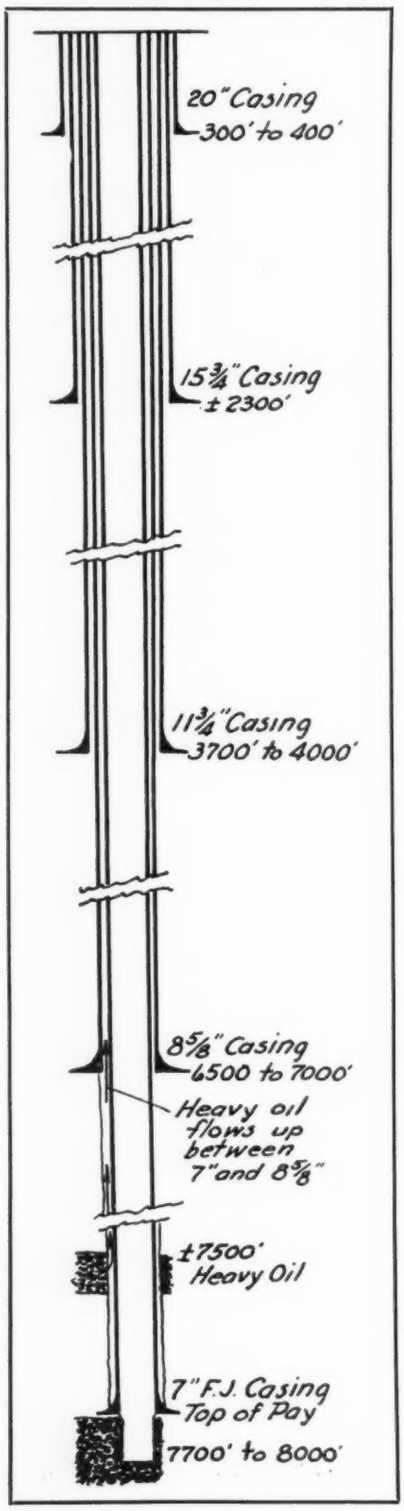
Mud is made from shale that outcrops near the Khaur field and is hauled ten miles to the Dhulian wells. This mud makes a fluid of 90 to 94 lb. per cu. ft. that is readily pumpable. There is plenty of shale in the Dhulian field but it makes a fluid weighing only 74 lb. per cu. ft. when thin enough to be pumpable. Mud pumps are 7¼ in. by 14 in. by 16 in. and 7¼ in. by 14 in. by 18 in. and are of late design.

Fig. 4. Typical casing program for wells in Dhulian field



The casing program includes 20-in., 15¾-in., 11¾-in., and 8⅝-inch. When the 8⅝-in. string must be set high, a string of 7-in. flush-joint is also run as shown in Fig. 4. The producing limestone stands-up well and no liners are used.

In this field there are three or four fresh water zones between the depths of 800 and 4200 feet. These zones sometimes flow 10,000 to 15,000 bbl. per day at pressures ranging from 200 to 400 lb. per sq. in., thus causing considerable difficulty during drilling. By experiment it has been found that if the top waters are excluded from the well by application of high pressure, crevices in the overlying formations permit the water to rise to the surface through the ground adjacent to the well. When pressure of the waters in the lower strata is overcome the mud fluid is lost unless a balanced pressure is maintained. As a balanced pressure is difficult to maintain, the present practice is to allow the water to flow naturally, even when running casing, and after the casing has been landed to let it flow between the strings. This water is gathered and used for general field service.

When running casing in this manner, however, there is always the danger of bridges being formed. It may require a week to run a string of casing, as the pipe is circulated down the hole joint by joint; however, it takes only six to eight months to complete a well in this field.

When water zones are being drilled the flow of water is so great that no attempt is made to use mud while rotating. After the bit has reached bottom after a round trip, a few hundred bbl. of mud is circulated to start, and when the tools are pulled, 400 or 500 bbl. of mud are pumped into the well.

The heavy water flows are shut-off by setting the 11¾-in. casing, and the 90- to 94-lb. mud is used thereafter. At a depth of 6500 to 7500 ft. a heavy black oil is encountered. This is produced between the 8⅝-in. string and the 7-in. flush-joint casing, which is cemented on top of the big producing zone. The heavy oil comes from Murree shales and below these strata is a hard lime, usually about 400 ft. thick. Beneath the hard lime is the soft lime in which the oil is found.

Production Practice

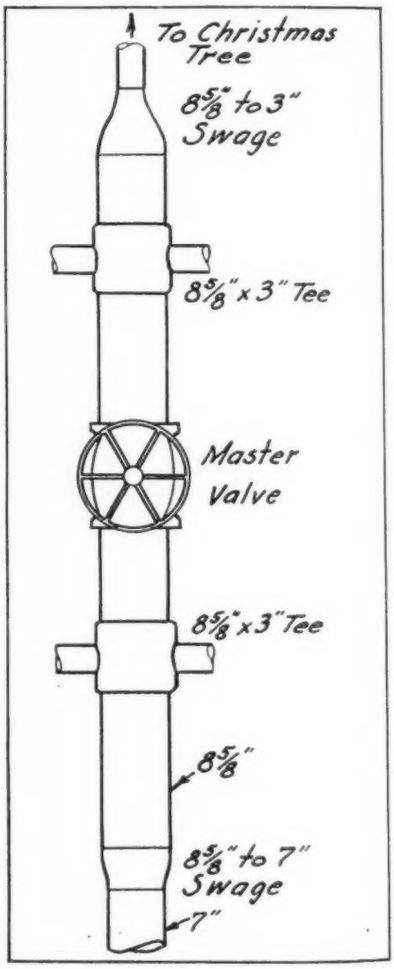
The surface connections on the 7-in. string below the Christmas tree are indicated in Fig. 5. The big production flows through the 7-in. casing and the heavy oil is produced through the annular space between the 7-in. and 8⅝-in. strings.

Very little gas accompanies the oil, the gas/oil ratio being only 300 cu. ft. per barrel. The separators are the 175-lb. type.

A small topping plant at the field processes the small production of black oil. This plant has a capacity of 400 bbl. per day but is not refining that much oil yet. The gasoline is used for field operations and any excess is mixed with the light oil and pumped to the refinery at Rawalpindi. The residue from the field plant is used for fuel oil.

It is too early to make any estimate of the possibilities of the Dhulian field. Thorough development probably will be delayed until facilities are available for refining the production, which is now pinched-in to a small fraction of the potential. The Attock Oil Company has developed an efficient operating technique and should production from likely areas nearby prove to be comparable to that of Dhulian field, the Punjab may become an oil-producing area as important as Burma.

Fig. 5. Typical surface equipment for wells in Dhulian field



Unitized Fields of Iran Developed and Produced by Scientific Methods

Field research and complete records facilitate reservoir control, resulting in maximum economy of operation

By RALPH H. KING

THE producing fields of Iran (formerly Persia) are situated in the geosyncline that occupies most of southern and southwestern Iran and extends northwestward into Iraq. The producing structures are local anticlines and the reservoir rock is the Asmari limestone or the equivalent Kalhur limestone. This formation is overlain by the incompetent beds of the Fars Series. The Asmari limestone is dense and hard and serves as a reservoir only in the areas where it has been fractured by folding. Several of the local structures have been tested and proved to be productive.

The principal producing fields are the Masjid-i-Sulaiman field 125 miles northeast of Abadan at the head of the Persian Gulf, the Haft Kel field 40 miles south of the Masjid-i-Sulaiman field, the Gach Saran (Gach-i-Qaraghuli) field 125 miles southeast of the Haft Kel field, and the Naft-i-Shah field on the northwest boundary of Iran. The Naft Khaneh field of Iraq is an extension of this last-named field.

Masjid-i-Sulaiman Field

The Masjid-i-Sulaiman field was the first to be discovered, the discovery well completed in 1908 having an initial production of 200 bbl. per day. A few early wells were drilled near the discovery well, which was later found to be on the west side of the structure. The wells were spaced 500 ft. apart. Not until after the World War was any attempt made to outline the field.

The structure is an elongate anticline 17 miles long and 4 miles wide, comprising approximately 45,000 acres. The closure above the water-oil contact is 2200 ft., but the Asmari limestone is only 900 ft. thick and the lower 500 ft. is much less prolific than the upper 400 feet.

The depth of the wells ranges from 2000 to 3000 ft., depending upon the topography and structural position. Between 300 and 400 wells have been drilled and of these many have been plugged and some others serve as observation wells for oil, for water, and for gas.

The casing consists of 11¾-in. set at a depth of 2200 ft. and 8⅝-in. set at the top of the producing formation, or a single string of 10¾-inch.

The oil enters a 4½-ft. by 40-ft. separator containing no baffles. At the gas outlet is a diaphragm-type gas relief valve that maintains a slight back-pressure on the well. The back-pressure usually does not exceed 60 pounds. Both the oil and gas leaving the separator are measured by orifice meters. A gas gathering system and gasoline plant are now being installed.

The annual production of this field since 1929 is as follows:

Year	*Tons*	*Bbl. (Approx.)*
1929	5,434,071	41,530,000
1930	4,925,869	37,650,000
1931	4,248,086	32,470,000
1932	4,490,010	34,440,000
1933	4,999,635	38,850,000
1934	5,338,733	40,800,000
1935	4,227,884	32,300,000
1936	3,641,247	27,820,000
1937	4,375,112*	33,110,000

*December production estimated.

These production figures include crude and refined products piped to the coast but do not include surplus products returned to the reservoir. A topping plant having a rated capacity of 75,000 bbl. per day is operated intermittently as the demand for crude and finished products varies. Benzine, fuel oil, and an intermediate product are produced. The surplus products are returned to the reservoir under pressure, thereby increasing the flexibility of operation, dispensing with tank storage, and increasing the expected ultimate recovery of light fractions, thereby increasing production efficiency. Before the residues are returned to the reservoir their viscosity is reduced by regassing with surplus gas at a pressure of 35 lb. per sq. inch. This program was begun in 1929 and the results have justified its continuance.

Production from this field is carefully controlled, and the individual wells are closed-in if their gas/oil ratio begins to increase. This procedure is possible because the Anglo-Iranian Oil Company owns the entire field. As a result of this method of operation the reservoir-pressure decline has scarcely exceeded one lb. per sq. in. per year and no well is producing any water, although the wells are particularly sensitive to edge-water encroachment.

Complete records of the history of all wells permit accurate prediction of the time when any particular well will begin to produce at an excessive gas/oil ratio. Before that time arrives another well has been completed to maintain the rate of production from the field.

In 1935 acid-treatment was introduced as a means of reducing bottom-hole pressure differentials and thereby increasing the flowing life of the wells. The usual treatment consists of the introduction of three charges of 500 gal. of 15 percent hydrochloric acid inhibited by refinery acid sludge, but treatments of one or two charges have been successful. The method is especially successful in fissured areas.

Haft Kel Field

This field, discovered in 1923, first produced oil in commercial quantity in 1929. The structure closely resembles the Masjid-i-Sulaiman structure, except that the depth is slightly greater and the pressure is greater. By 1936 the main structure had been delimited and

twelve production and eight water observation wells had been drilled, about one producing well to five sq. miles. The area is regarded as "drilled-up" unless further development reveals unexpected geologic conditions. The proved area includes about 50 sq. miles. Under standard test conditions initial production averaged 20,000 bbl. per day, and some wells produced as much as 40,000 bbl. per day against a back-pressure of 600 lb. per sq. inch. The closed-in pressures averaged about 700 lb. and the gas/oil ratios about 395 cu. ft. per barrel. Depth of the wells ranges from 2000 to 5000 ft., owing to the broken topography and great structural relief.

The same methods of reservoir control are used that have been so successfully employed in the Masjid-i-Sulaiman field, and seemingly they are equally beneficial here.

Flowing pressure of the wells is about 500 pounds. It is therefore feasible to retain gasoline fractions in the crude oil by removing the non-condensible fractions by stage separation. The well-head separator pressure of 500 lb. is reduced by stages at the central tank battery and the crude is delivered to the pipe line at atmospheric pressure or at a pressure of 10 lb. according to refinery requirements. By stage separation all but 20 percent of the n-butane and 35 percent of the propane is retained in the oil, in contrast to flash separation whereby 70 percent of the butane is lost. The hydrogen sulphide content of the gas from various stages is as follows:

Stage	*Percent*
500-lb.	1.7
184-lb.	2.9
80-lb.	4.8
32-lb.	7.1
18-lb.	9.5
10-lb.	11.2

Production of this field since 1929 is as follows:

Year	*Tons*	*Bbl. (Approx.)*
1929 (2 mo.)	26,884	210,000
1930	1,013,433	7,750,000
1931	1,502,412	11,480,000
1932	1,955,798	14,930,000
1933	2,087,071	15,880,000
1934	2,198,639	16,810,000
1935	3,231,177	24,690,000
1936	4,473,849	34,200,000
1937*	5,693,849	43,480,000

*December production estimated.

Gach-Saran Field

Exploratory drilling in this area was begun in 1926, a cable-tool rig being used for drilling the early test wells. Four attempts were abandoned because the equipment was not adequate for drilling through the high-pressure zones encountered. From 1930 until 1936 the area was neglected but in 1936 Well No. 3 was cleaned and deepened by rotary to a depth of 3393 feet. The well penetrated the Asmari limestone seven ft. and flowed at the rate of 33,000 bbl. per day. Flowing pressure was 850 pounds. Initial production of the second and third producing wells was 3000 and 33,000 bbl. per day respectively.

The structure is an asymmetric anticline and the crest at the surface does not overlie the crest of the fold in the Asmari limestone. Consequently the first wells were drilled well out on the steep flank. Subsurface geology and geophysical exploration indicated the true conditions and the wells drilled later were more favorably located.

Three new heavy rotary rigs are being moved to the field and will be used in drilling additional wells until the field is delimited. About eight wells have been completed but as there is no pipe line the wells are closed-in. This field gives evidence of being the largest yet discovered in Iran.

Naft-i-Shah Field

The Naft-i-Shah field and Naft Khaneh field in Iraq are in reality one field. The boundary between the two countries is also the boundary between the properties of the Khanaqin Oil Company of Iraq and those of the Kermanshah Petroleum Oil Company in Iran. Both companies are controlled by the Anglo-Iranian Oil Company, however, so the field is being developed as a unit.

The producing formation in this field is equivalent to the Asmari limestone of the other fields but is known as the Kalhur limestone. It is 235 ft. thick, and is most productive where most severely fractured. Recently the policy of returning surplus products to the reservoir was applied to this field.

The production of 7000 bbl. per day is unimportant in comparison with that of the larger fields lying to the southeastward. In 1935 a 3-in. pipe line was constructed between the field and the town of Kermanshah 145 miles away and a topping plant was built in the town. All oil produced in the field is piped to this plant and processed for local distribution.

Other Areas

Two sweet gas wells have been drilled on the White Oil Springs structure in the Haft Kel trend. The pressure at a depth of 2900 ft. is 2800 pounds.

At Pazanun the gas pressure at a depth of 5600 ft. is 4000 pounds.

Areas that will be explored further as a result of production or favorable showing in wells previously drilled include Mamatain southeast of Haft Kel on the same trend, Agha Jari on the Pazanun trend, and Gach-i-Pokok and other structures in the Gach Saran area.

The Kuh-i-mund structure on the coast 40 or 50 miles southeast of Bushire has yielded no production, although a test well was drilled into Cretaceous strata. Still farther southeast is the Kishm Island structure, where a test recently drilled to a depth of 8400 ft. is reported to have reached only the top of the Cretaceous system.

Drilling Methods

More than 400 wells have been drilled in Iran. Many were drilled as observation or input wells, and others were drilled as producing wells but were closed-in when the gas/oil ratio became excessive. About 12 wells are now being drilled, the most active area being the Gach-Saran field, which has not yet been outlined. Formerly cable tools were used for all drilling but the high pressures encountered necessitated the change to rotary rigs. The depth of most wells is between 3000 and 5000 ft., but four wells have been drilled that should be regarded as deep tests.

Yamaha No. 2 well was drilled to a depth of 8960 ft. in 1931 and the last 6333 ft. was open hole. Electric power was used for drilling and the operators at that time believed this to be the deepest well thus drilled.

Qishm No. 3 well was drilled to a depth of 8294 ft. in 1935. The last 5300 ft. was pressure-drilled and mud of 1.6 specific gravity was used to maintain a pressure of 600 to 1100 lb. when drilling and running casing.

Pirgah No. 2 well was drilled to a depth of 10,025 ft. in ten months. At a depth of 6000 ft. heaving shale became troublesome and a mud of 1.95 specific gravity was used to combat it. A brine shale mud of 1.3 specific gravity was used as a base and barytes added to obtain the required weight. As additional shale was drilled the mud became too viscous and was treated with magnesium chloride.

Zeloi No. 4 well was drilled to a depth of 11,190 ft. in ten months. At a depth of 9700 ft. troublesome formations were drilled and a mud of 1.55 specific gravity was substituted for the brine shale mud of 1.42 specific gravity that had been used in drilling to that depth.

The same rig drilled both the Pirgah No. 2 and Zeloi No. 4 without any serious mechanical difficulty. In drilling the latter it was twice necessary to

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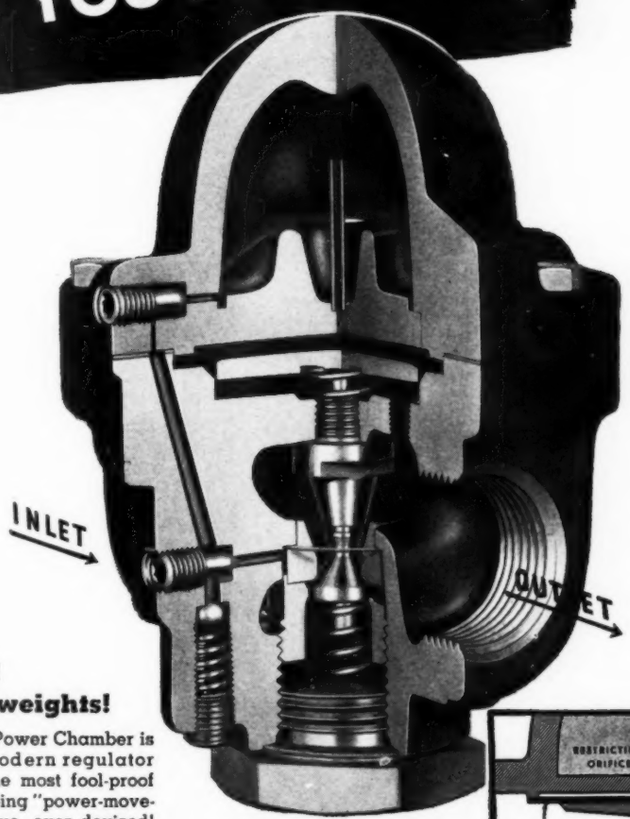

Grove Universal Regulators greatly simplify and improve pressure control at the oil wells or on gas pipe lines. Pressure pulsation and valve chatter are entirely absent. *As for safety;*—when the diaphragm in an ordinary regulator ruptures full pressure goes into the line or to atmosphere. No Grove diaphragm has yet broken but if it should the valve seats itself and *all flow stops!* Grove's smooth flow may be used to discharge directly into a displacement gas meter. Freedom from shocks, pulsations and overloads protects other apparatus in the line against damage. You can install a Grove Universal Regulator and "forget it"—it works without being "nursed" and it's tamper-proof.

No Springs!
No Counterweights!

The Grove-Boyle Power Chamber is the miracle of modern regulator design. It uses the most fool-proof method of developing "power-movement" for the valve, ever devised! No springs! No Counterweights! Just a precision volume of gas—enclosed—sealed into the dome. The Grove Gas Dome and Grove-Boyle Power Chamber operating together *modulating* Boyle's Law of enclosed gases to generate "flexible power" impossible for any spring or counterweight to imitate!

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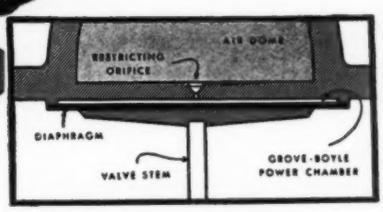
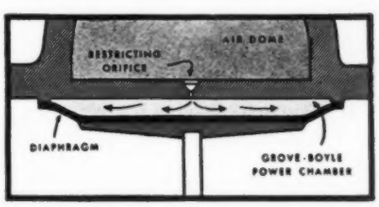


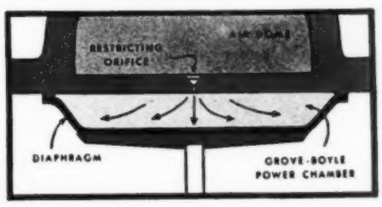
Extremely Small Volume

To make clear the principles of operation the "thinness" of the Grove-Boyle Power Chamber should be considered. Only 1/64" separates diaphragm and dome plate when valve is seated. Should the valve then move but 1/64" the volume of this chamber doubles instantly and so does the force resisting the valve movement.



Flexible Control

If the first 1/64" valve movement increases opposing forces by 100% the second 1/64" adds but 50% and the third but 25%, etc. Hence, when the valve "starts toward its seat" it encounters a "live elasticity" unlike any force that can possibly be generated by a coil-spring, counterweight or dash-pot!



Full Volume Flow

Throughout its entire range the Grove Regulator is *extremely sensitive* to pressure or volume variation. This is due to the modulating effect of the restricting orifice between the gas dome and the Grove-Boyle Power Chamber — because in every operating position quick movement of the valve is powerfully resisted.

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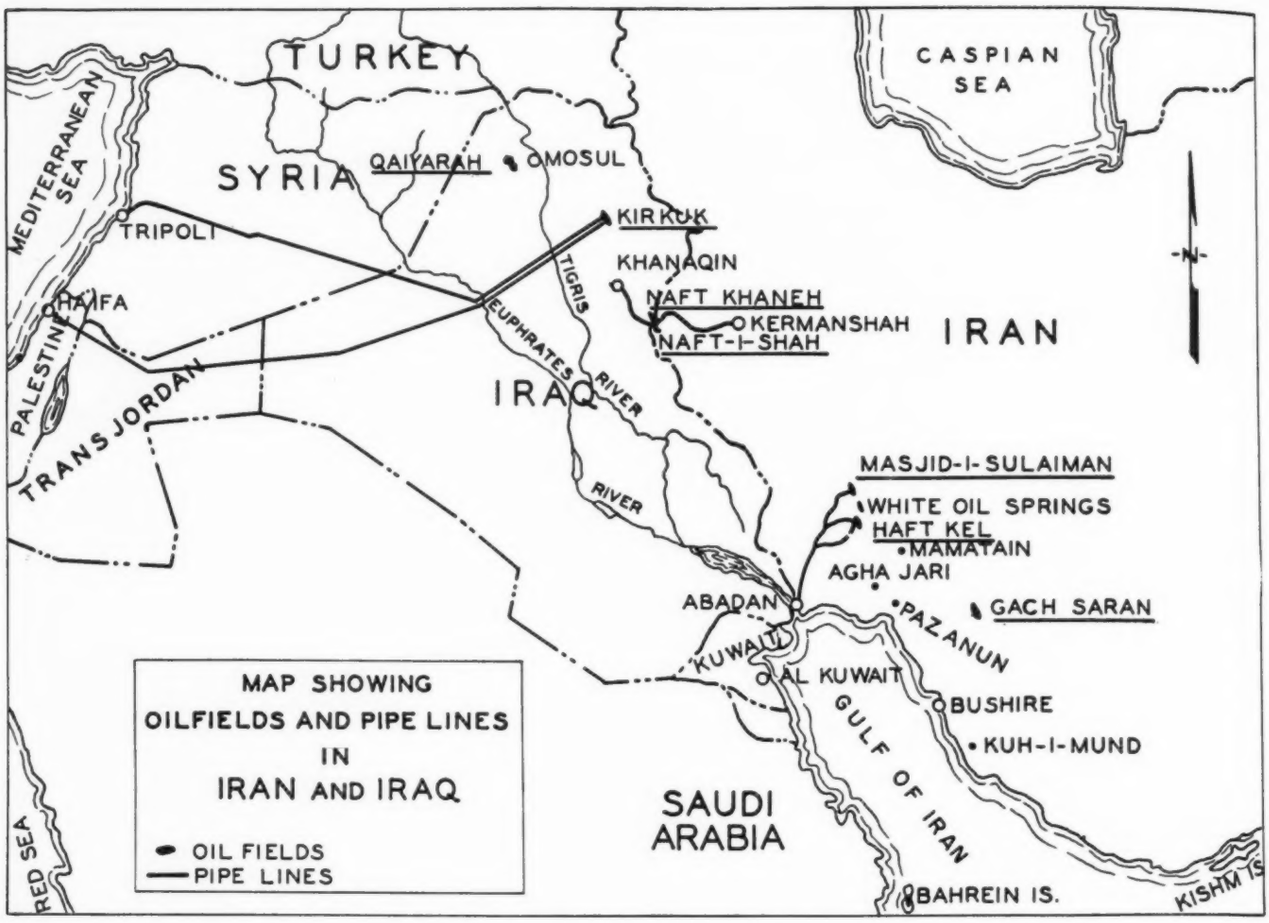

plug-back crooked hole but there were no other delays.

All rotary rigs are equipped in accordance with the following standards: 136-ft. A.P.I. standard derrick, 22-ft. floor-to-floor cellar, movable steel floor supports, three mud pumps, 12-in. by 12-in. steam engine, English type portable boilers, master gate provided with extension control, blowout preventer, and 3½-in. drill pipe. The drawworks is a three-shaft, four-speed unit type equipped with hydromatic brake. A double deck crown block and 5-sheave traveling block are used.

Special Instruments

The research staff of the Anglo-Iranian Oil Company has devised several special methods and pieces of apparatus for use in making production measurements. Among these are the canvas bag method of measuring high-pressure gas production during an oil production test[1], an ingenious but not particularly advantageous bottom-hole sampler that does not flash the oil and gas into an empty space, and a maximum-reading bottom-hole pressure recorder, said to be accurate to 2½ lb. at a pressure of 2500 pounds.

The bottom-hole pressure recorder consists of a glass tube three ft. long and ¾ in. in diameter at the larger end, narrowing to a ½-mm. tube 20 in. long. The inside of the fine tube is silvered and the tube is filled with dry air at a pressure dependent upon the range of pressures to be measured. The large part of the tube is filled with mercury and the tube is placed in a mercury-sealed steel case. The well pressure forces mercury up the tube, dissolving the silver. Pressure at several depths can be measured if the instrument is raised to the surface each time and the reading recorded and if the readings are made at progressively greater depths.

After the readings have been made the tube is taken to the laboratory, placed in a steel case provided with a celluloid window, and connected to a dead-weight tester. The pressures required to raise the mercury column to the heights measured are noted and the necessary temperature correction applied.

Abadan Refinery

The refinery at Abadan is one of the largest in the world. Crude oil is distilled in three stages, at a pressure of 50 lb., at atmospheric pressure, and under vacuum. Three of the six stills have a combined capacity of 80,000 bbl. per day at high pressure and atmospheric pressure, and the 24,000 bbl. of residue is processed in a separate vacuum unit. The fourth unit completely refines 28,000 bbl. of crude per day. The other two units each have a capacity of 75,000 bbl. per day but their vacuum stages can treat only 15,000 bbl. of residue per day, or about half the residue from the still.

In addition to the main stills there are several shell and pipe stills operating at atmospheric pressure that have a total capacity of 60,000 bbl. per day.

The first cracking equipment was built in 1931 and the cracking capacity now exceeds 100,000 bbl. per day.

One 10-in. line and three 12-in. lines transport oil and refined products to the refinery at Abadan from the Masjid-i-Sulaiman and Haft Kel fields. All lines are laid above-ground, regardless of size or fluid transported. There are no tanks in the pipe line system, as the oil is metered into the lines at the fields and is metered from the line at the refinery.

[1] "Some Applications of Metering in Oil Field Operations," by Capt. D. Comins, M.C., page 167.

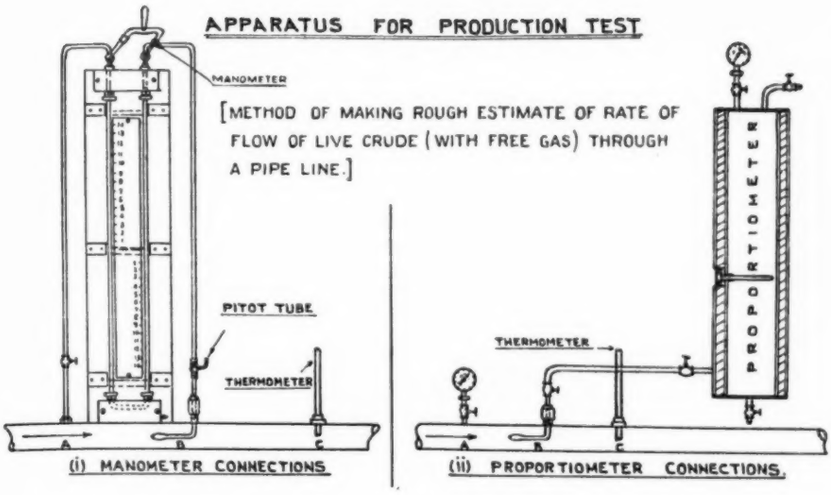

Fig. 1

By

CAPTAIN D. COMINS,

M.C., R.E. (Retired), M. Am. Inst. M.E. (Member)

Some Applications of Metering in Oilfield Operations*

SYNOPSIS

Owing to the trend towards primary processing of crude production on site, oilfields with their topping plants, stabilization plants, or gasoline-recovery plants are tending to resemble refineries. Examples are quoted. Thus, routine applications of metering in oilfields—briefly outlined—are mostly the same as discussed in Mr. Adey's paper†, and in all these, routine technique is similar except in detail, the only variables being in density and viscosity of fluid metered, in flowing pressure and temperature, and in steadiness of flow.

A special technique is, however, necessary in measurement—in the broader sense of metering—of "live" crude production; *i.e.* of crude containing dissolved gas under pressure, with or without the free gas associated with it at the pressure of measurement. There are two salient operations in which this is required: in measuring the production rate or gas/oil ratio of a well that cannot conveniently be tested to an individual separator or tank, and in routine operation of multistage gas separation as a means of gasoline recovery, or, rather, of gasoline retention.

Comparatively little having been published on these specialized applications of metering, the body of the paper is a description of these as practiced on the Iranian fields.

Points of emphasis are a detailed statement of apparatus and technique of the "Portable Tank and Gas Bags" method of estimating production and an outline of principles and operation of Multistage Gas Separation and of the rôle of metering in assessing the results achieved.

This description of special applications of metering is prefaced by a tentative discussion of the comparative accuracy of routine orifice metering and of tank dipping—a subject on which data from members' personal experience in different countries would be welcomed.

AS suggested by its title, it is proposed in this paper to discuss only certain specialized applications of metering in oilfields, which may be of some interest in that comparatively little has so far been published regarding these. No attempt is made to discuss the many other routine applications of metering in oilfields or the details of operating and instrumental technique incidental to accuracy in such work, the latter being left to specialists on the operating and manufacturing sides.

As regards the former, owing to the modern trend toward primary processing of crude production on site, oilfields, with their topping plants and their stabilization plants or gasoline recovery plants, are tending more and more to resemble refineries. Examples that may be quoted are the Masjid-i-Sulaiman field in Iran, where, in the interests of flexibility in meeting market requirements with minimum pipeline throughput, crude is processed as and when and how required and surplus products returned to the reservoir; and the Kirkuk field in Iraq, where, in order to retain the maximum amount of desirable light fractions and the minimum amount of undesirable light fractions in the crude for delivery to the long pipe line to the Mediterranean, crude and dissolved gas production is stabilized under pressure[1]—an operation until recently confined to refineries. Similar plants are also in operation on the Basile field, Louisiana,[2] and in the Tepetate field, Louisiana.[3]

Thus the routine applications of metering in oilfields are mostly the same nowadays as those discussed in Mr. Adey's paper†. As in the refineries, a number of different liquids and gases require to be metered—water for domestic purposes, boilers, or cooling towers; crude to process plants or pipeline; circulating oil in gasoline absorption plants; products and gasoline from process plants; surplus products re-injected to reservoirs; steam to engines or turbines; lean gas from crude separators; lean gas from gasoline recovery plants; lean gas to boilers, engines, or turbines; lean gas to repressuring of reservoirs; lean gas to domestic fuel; rich gas from separators; rich gas from crude process plants; rich gas to gasoline recovery plants; rich gas to regassing and rejuvenation of surplus products re-injected to reservoirs.

In all these jobs (the above catalogue of which does not claim to be

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*Paper presented for discussion at the One Hundred Seventy-ninth General Meeting of the Institution of Petroleum Technologists (now the Institute of Petroleum) held on January 11th, 1938.

†S. W. Adey, The Application of Automatic Control to Refinery Process Operations, page 192.

[1]Anon., *World Petroleum*, 1937, February, p. 67.

[2]E. O. Bennett, *The Petroleum Engineer*, 1936, February, p. 135.

[3]E. O. Bennett and C. R. Williams, *Oil & Gas Journal*, 1937, May 20th, p. 55.

(*Continued on Page 171*)

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3. Attain greater depths with equal safety.

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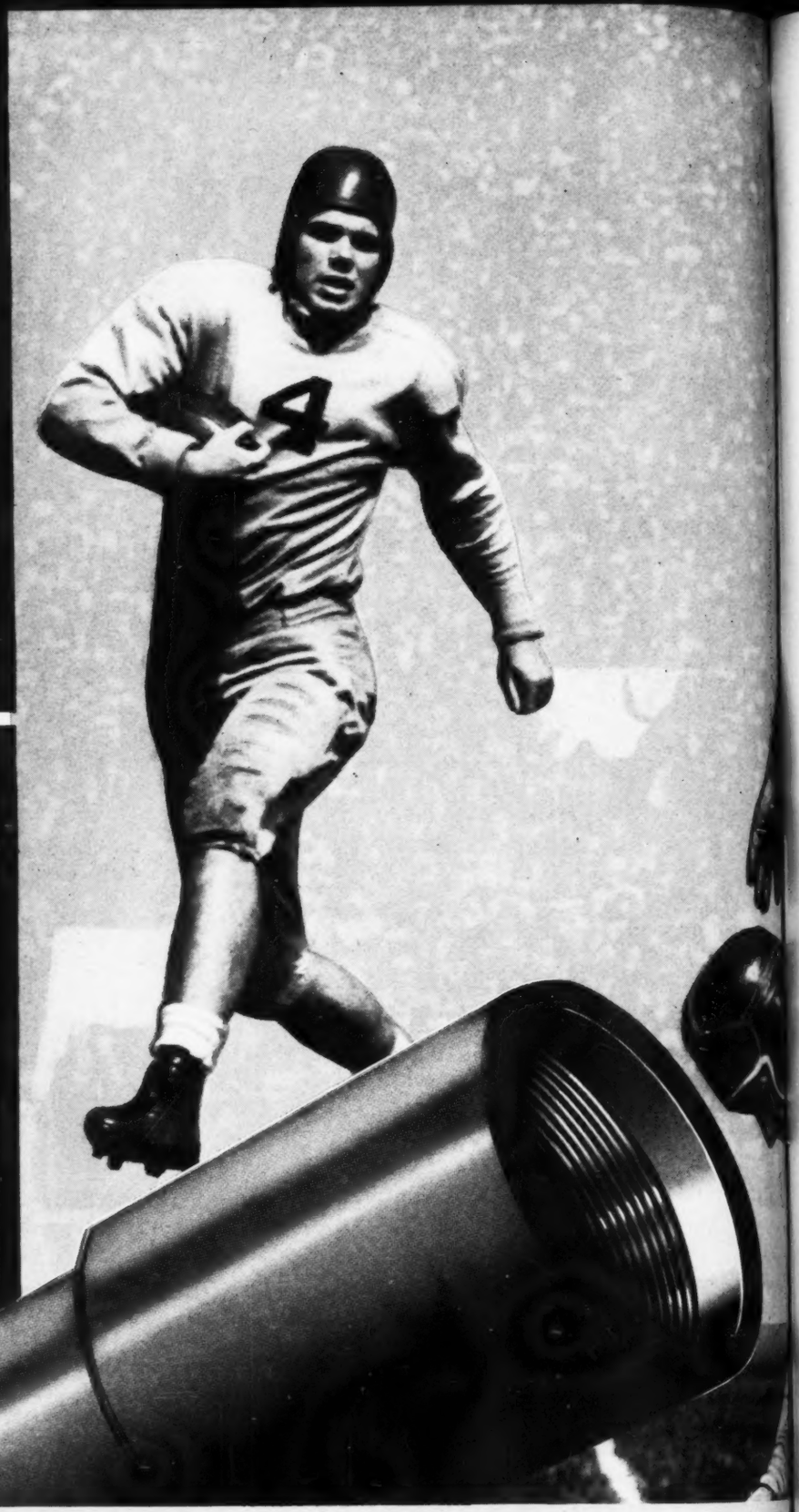

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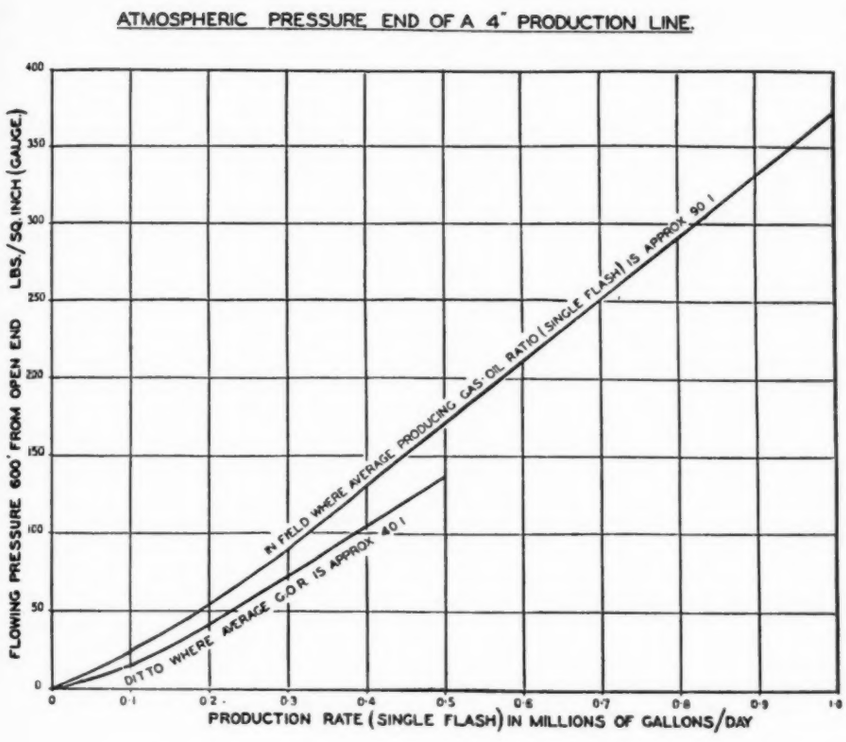

Fig. 2. Relation between production rate of wells and flowing pressure at a point 600 ft. from the atmospheric pressure end of a 4-in. production line

(*Continued from Page 167*)

comprehensive) the routine technique of metering is more or less identical, except in detail; the only variables to be taken care of being in the density and viscosity of the fluid to be metered, the temperature and pressure at which it is flowing, and the steadiness of flow. It is probably a safe generalization to say that the only oilfield operations in which a different technique is necessary from that in refineries is in the metering of "live" crude production and in the measurement of mud fluid losses while drilling into a potential oil- or gas-bearing formation. By "live" crude is meant crude from wells containing dissolved gas under pressure—such crude being either with or without the free gas associated with it at the particular pressure of metering.

The question of mud fluid losses may be dismissed very briefly. Its importance lies in the fact that appreciable losses indicate that favorable reservoir conditions have been encountered, the mud fluid running away into fractured or very porous formation. It also indicates that the pressure of mud fluid in the well exceeds the reservoir pressure and should be reduced in order to minimize the risk of sealing-off the formation. Conversely, of course, an increase in the rate of mud fluid return to surface indicates that a show of gas, oil, or water, under higher reservoir pressure than that of the uncontaminated mud fluid, has been struck and is beginning to enter the bottom of the well. The method of measuring the mud fluid gains or losses is merely by dipping the level of mud fluid in the mud storage tank from which the mud is drawn and to which it returns after circulation.

Comparative Accuracy of Metering and Tank Dips

Before going on to discuss measurement of "live" crude production, which is the main objective of this paper, this may be a suitable moment to raise a point of very considerable interest in the oil industry and, of course, to meter manufacturers, in the hope of provoking profitable discussion on the

Fig. 3. Diagrammatic illustration of method of measuring production and gas/oil ratio of wells by portable tank and gas bags

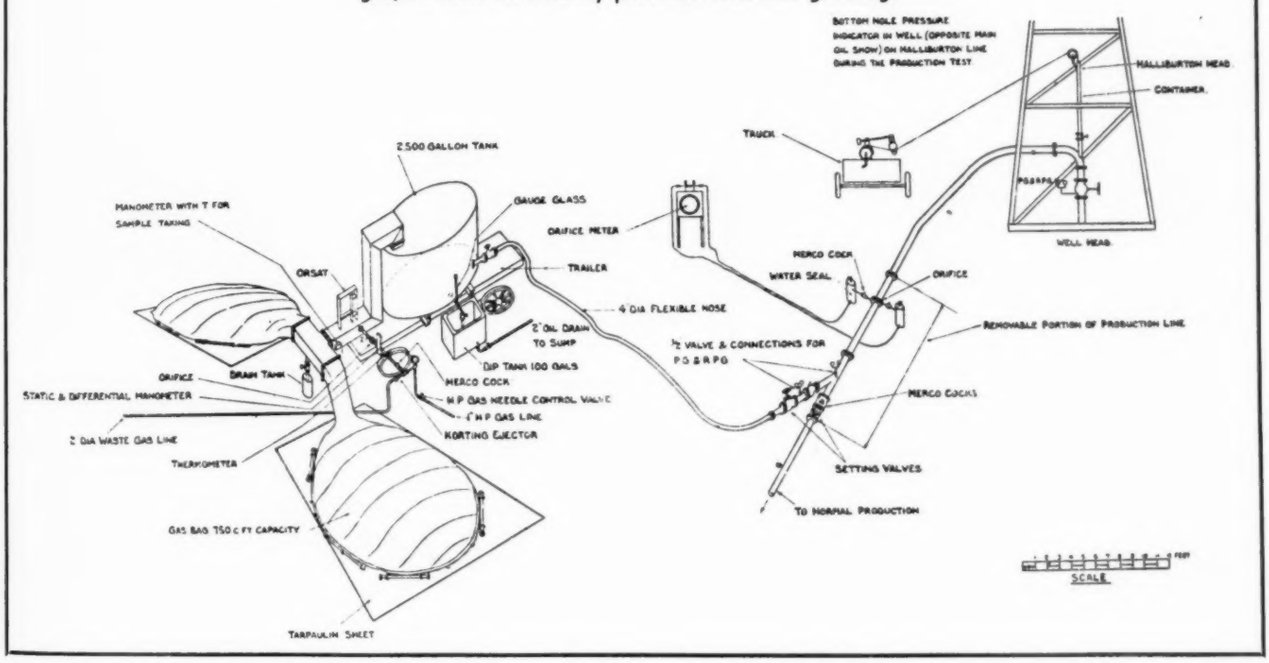

Fig. 4. Photograph of Y-piece, valves, and orifice fittings

subject. I refer to the relative accuracy of orifice metering as compared with tank dipping.

It is probably common ground that metering has been adopted by most oil companies for their internal operations on producing fields, pipelines, and refineries, as being far cheaper and more convenient than tank dipping and as being sufficiently accurate for all practical purposes and for internal balance sheets of crude, gas, and products. It may indeed be claimed that the accuracy obtained by good metering—all technical precautions being taken—is of the same order as that obtained in tank dipping, where the latter is not scientifically controlled.

Although on the face of it tank dipping would appear to be one of the simplest of oilfield operations, there are various factors that make for inaccuracy unless very precise quantitative corrections for these are made. This is a subject in itself; but among these factors may be mentioned the variation in cross-section of the tank itself, the measurement of the average temperature of the tank at the time of measurement, the sampling of the crude for determination of the average specific gravity in the tank, and the correction of the volume of the oil from that at the temperature of measurement to that at a standard temperature such as 60 deg. fahrenheit. Of these, the last is the most difficult correction, particularly with waxy oils, with which it is understood that standard routine correction for temperature may be very inaccurate and special precautions are necessary.

There is, however, no question that tank dipping, when such factors are properly taken care of on a scientific basis and all technical precautions observed, is definitely more accurate than metering over any comparatively short period of test.

One is on more debatable ground in attempting to put these statements on a quantitative basis. As a starting-point for discussion, ± 1 percent for metering with all technical precautions taken, a similar or perhaps slightly better figure for ordinary tank dipping, and ± ½ percent, or even, possibly, ± ¼ percent, for tank dipping under precise scientific control, are suggested, all these figures being applicable to comparative short-period tests. (The ± 1 percent figure for metering given above refers, of course, to liquids, the comparison being with tank dips. For gases the accuracy of metering under best conditions is generally accepted to be about ± 2 percent.)

Where tonnage in tanks is directly calculated from readings of a mercury column connected to the bottom of the tank through a seal, the comparative accuracy of tank figures is still greater; as, in this method, the conversion of volume into weight, which is one of the major sources of inaccuracy in the calculation of tonnage figures from actual tank dips, is automatically avoided.

As tonnage rather than volumetric figures are the rule for fiscal and sales purposes, it is likely that this method of tank measurement will be increasingly adopted. In fact, the author is informed by the Iraq Petroleum Company that, in agreement with the Iraq Government, they have recently installed this method for fiscal purposes.

Over long periods the difference between the relative accuracy of metering and of tank dipping should be even less than between the figures quoted above, provided that "systematic" errors are reduced to a minimum in both methods. "Systematic" errors are re-

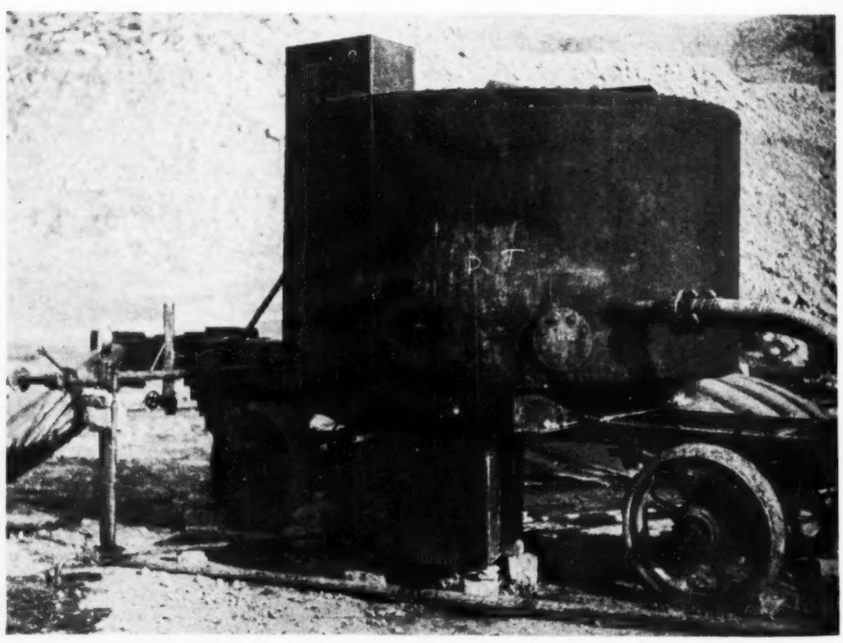

Fig. 5. Photograph of the main tank showing dip tank, gauge glass, and tangential inlet

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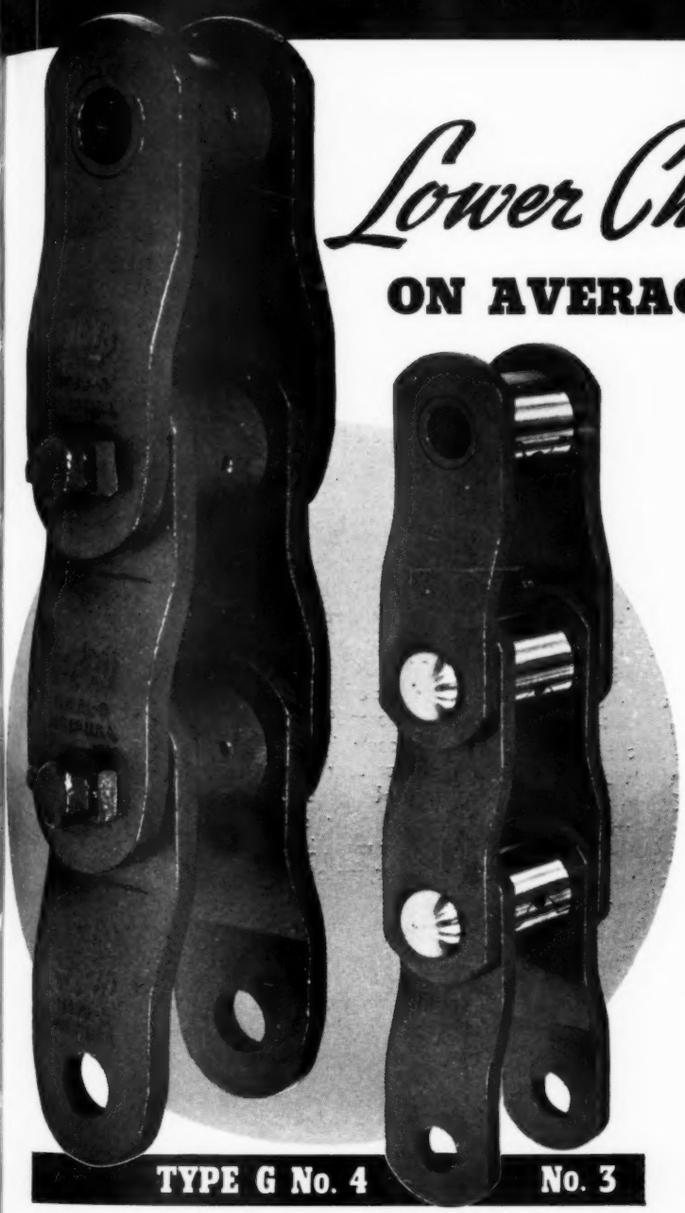

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ferred to in the sense used by Mr. E. S. L. Beale, who has made a deep study of the physical and mathematical technique of both metering[4] and tank dipping[5]—as being errors that will not tend to cancel themselves out over a long period or a large number of observations, as will errors of visual observation or approximation. Such "systematic" errors may be due either to approximate methods of calculation and to approximations in the mathematical constants employed, both of which sources of error are clearly avoidable; or to error in initial calibration—*e.g.* in tank dipping—of the tank itself; or, in orifice metering, of the orifice itself, particularly when metering viscous liquids. In orifice metering further sources of "systematic" error are faulty instrumentation and corrosion or wear of the orifice.

In orifice metering the initial calibration of the orifice is, of course, the most important factor, and a far greater degree of accuracy can be obtained where one definite product (or crude) is metered by a given instrument and the orifice is calibrated on site for this product against scientifically controlled tank dips.

Supporting the generalizations made earlier regarding the attitude of oil companies to metering, and the relative accuracy of metering as compared with tank dips, the following evidence may be quoted:—

(*a*) In a recent description[6] of the development work of the Mexican Eagle Company on the Poza Rica field, Messrs. Clark and Flinn, the Company's Chief Exploitation and Mechanical Engineers, respectively, state:—

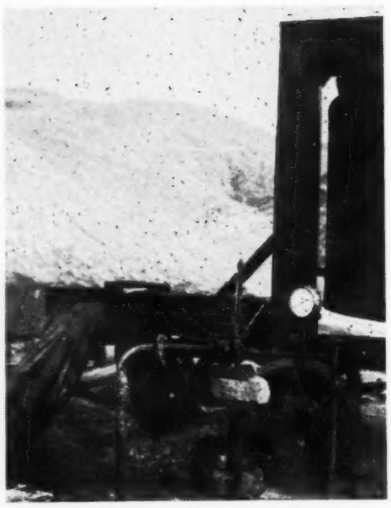

Fig. 7. Photograph showing throat of gas bags' connection to gas duct, high-pressure gas line, and Korting ejector

"The system of gauging by flow meter has proved entirely successful in Poza Rica, the average difference between the total volume of production as obtained by metering and by gauging in main storage tanks being in the neighborhood of one quarter of one percent over the past year. It is in fact generally considered that any error more probably lies in the tank gauging. When it is considered that for these wells 5000-bbl. tanks would normally be necessary for each well if measurement by gauge tanks were resorted to, and that equal accuracy in measurement by metering has been obtained at a cost of about $500 per well, some idea of the saving in equipment and operating cost may be realized. It is hoped, with the master meter and meters on the main pipe lines leading out of the district, that tank gauging may eventually be entirely eliminated."

(*b*) In a recent communication to the author, Messrs. George Kent state that they have carried out several lengthy tests in both Mexico and Roumania, following which the method of measurement by meter instead of by tank has been accepted in certain instances. The same firm have submitted data of further tests carried out on crude oil measurement. In these, on individual short tests, the divergence between meter and tank-dip results was usually of the order of ± 1.0 percent, but in three tests, which were repeated over a period of several days, the mean divergence was well below this figure.

(*c*) In Iran the Anglo-Iranian Oil Company rely on metering throughout their internal operations. Tank dips are used for measurement of crude and products sold or exported. (The figures obtained for the latter by tank dips normally tie-in within ± 1.0 percent to 1.5 percent with those determined by meter. In cases where the meter has been previously calibrated on site against scientifically controlled tank dips, the difference is, however, negligible.)

(*d*) The American Gas Association, as a result of exhaustive investigations, have reported[7] the tolerance of discharge coefficients for orifice plates, when carefully designed and accurately made, to be ± 0.5 percent for liquids, and that "for commercial work the tolerances must include some allowance for the pressure and temperature measuring devices as well as that for the orifice plate, and so the commercial accuracy will be somewhat less."

Similar data from other countries and oil companies would be welcomed in the discussion.

Metering "Live" Crude

Reverting now to the subject of metering "live" crude, there are two salient operations in which this is essential; in estimating the production rate or the production rate and producing gas/oil ratio of a well that for some reason cannot be satisfactorily or conveniently tested to an individual separator or tank; and in the routine operation of multistage gas separation as a means of gasoline recovery, or, rather, of gasoline retention. Each of these cases will be discussed in turn.

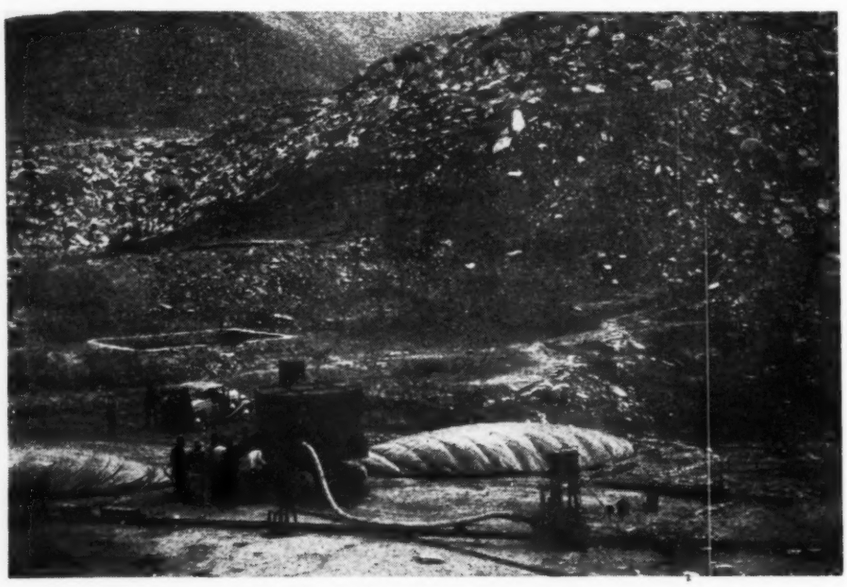

Fig. 6. Photograph showing gas bags inflated and general lay-out

[4]E. S. L. Beale, *Science of Petroleum*, 1938, 1, 688.
[5]E. S. L. Beale, *Journal Institute Petroleum Technology*, 1937, 23. No. 161, 213.
[6]E. Clark and F. A. Flinn, *Oil Weekly*, 1937, February 22, p. 67.
[7]American Gas Association (Natural Gas Department), 1935, Gas Measurement Committee Report No. 2, Appendices B and C.

(*Continued on Page 177*)

Fig. 8. Photograph showing orifice, static and differential manometer, thermometer and control cock in the 2-in. gas exhaust line from gas duct. (Also shows further view of ejector arrangements)

(*Continued from Page 174*)

The necessity or desirability of the first may arise when a well is first brought in and an estimate of crude and gas production capacity at various flowing pressures is desired before deciding on the capacity of separators or tanks to be installed, or on whether further deepening or possibly acid treatment is indicated. It may also arise when a similar survey of a completed well is desired, but the production layout is such that isolation of the production is impracticable. Repeat surveys of this nature are desirable at intervals dependent on the rate at which reservoir pressure and reservoir saturation pressure are dropping in the particular field concerned.

In the Iranian fields the earliest attempt to solve this problem was by the method that, as a matter of mainly historical interest, is illustrated. (Fig. 1.)

A station is selected on the production line where the flowing pressure is as low as possible and yet steady and the line is tapped for a static pressure gauge and a Pitot tube 10 in. downstream, which is arranged to work through a gland. The Pitot tube is first connected to the vertical cylinder shown and a rough approximation to the gas/oil ratio (at actual line pressure) obtained by flowing to the cylinder until a pressure just below static line pressure is built up in it. The high pressure manometer shown is then connected to the Pitot tube and the static pressure gauge connection and the differential pressure measured. Knowing the approximate gas/oil ratio at the pressure in the line, the head of fluid represented by the differential pressure may be calculated and thus the total flow of fluid, by ordinary Pitot tube formula. This total flow is then allocated betwen oil and gas in the proportions of the gas/oil ratio observed. The operation is repeated for varying depths of insertion of the Pitot tube into the line and the results averaged.

Estimation of production by this method is usually accurate within ± 10 percent on wells flowing steadily, where the line is reasonably small for the production and therefore full of a comparatively homogeneous mixture of oil and gas. In surging wells or in lines where layering of oil and gas is excessive, very large errors are possible— ± 25 percent and more. For these reasons and because the procedure of measuring the gas/oil ratio is not scientifically correct (though it yields reasonably good results as a first approximation), the method has been suspended, but, being very simple both in construction and operation, may prove useful for rough preliminary estimates in cases where other facilities are not for the moment available.

A very simple method of estimating well productions (but not gas/oil

(*Continued on Page 180*)

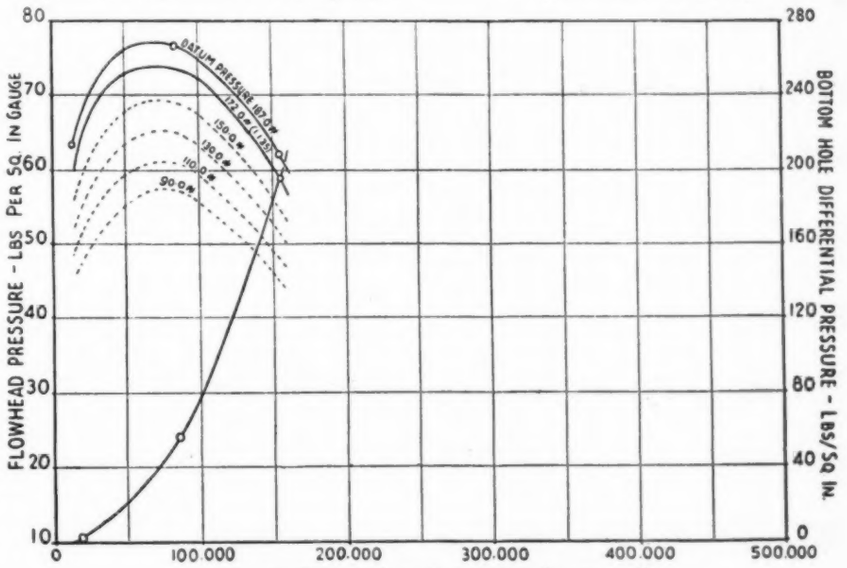

Fig. 9. Survey data from a moderate well

Production (gallons per day)	Flowhead Pressure (lb./sq. in. gauge)	B.H.D.P. (lb./sq. in.)	Bottom-Hole Temp. (° F.)	Gas-Oil Ratio (at a temp. of separation of 80° F.)	Percentage H_2S in Gas (at a temp. of separation of 80° F.)	Specific Gravity of Gas (at a temp. of separation of 80° F.)
155,000	62	197	96·2	42·2	11·4	.....
84,500	77	54·5	96·2	42·6	.....	.....
15,400	63	1	96·0	43·5	.....	.....
0	.....	0	96·1	.....	.....	.....

Flowhead elevation	10,844
Elevation of main limestone	8,569
Position of shows	8,558 / 8,502
Casing diameter (in.)	6·776
Date of tests	28/4/34
Datum pressure at date (lb. per sq. in. absolute)	187
Saturation pressure (lb. per sq. in. absolute)	578
Elevation of bottom-hole measurements	8,497
Static bottom-hole pressure (lb. per sq. in. absolute)	687·5

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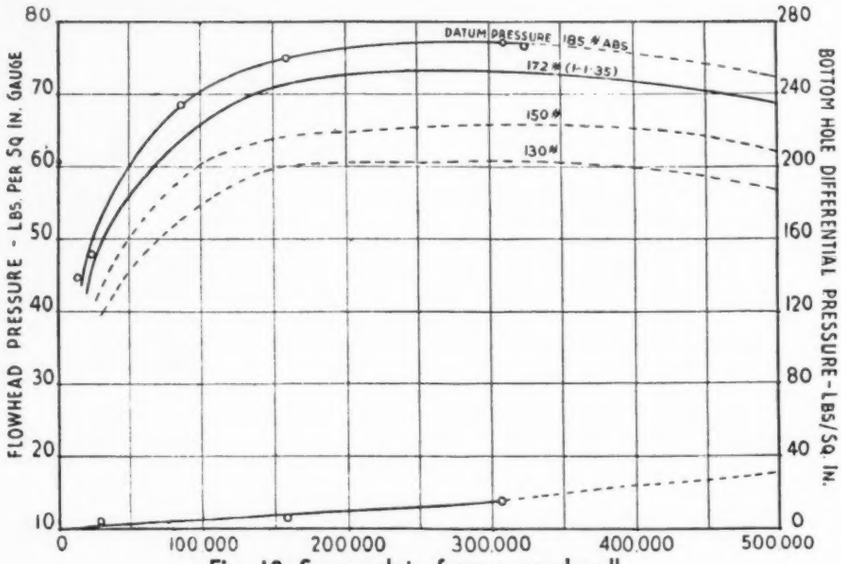


Fig. 10. Survey data from a good well

Production (gallons per day)	Flowhead Pressure (lb./sq. in. gauge)	B.H.D.P. (lb./sq. in.)	Bottom-Hole Temp. (° F.)	Gas-Oil Ratio (at a temp. of separation of 80° F.)	Percentage H_2S in Gas (at a temp. of separation of 80° F.)	Specific Gravity of Gas (at a temp. of separation of 80° F).
318,000	76·5	.....	.....	39·2	.....	1·149
306,000	77	12·5	.....	40·8	.....	.....
182,000	75	3·5	.....	40·4	10·6	.....
92,500	69	.....	.....	42·3	.....	1·153
21,500	47	1	90·2	42·7	.....	.....
13,000	44	.....	.....	43·8	.....	1·143
0	.....	0	90·2	.....	.....	.....

Flowhead elevation	10,978
Elevation of main limestone	9,119
Position of shows	{9,078 / 9,045 / 9,001
Casing diameter (in.)	8·291
Date of tests	8/5/34
Datum pressure at date (lb. per sq. in. absolute)	185
Saturation pressure (lb. per sq. in. absolute)	489
Elevation of bottom-hole measurements	9,039
Static bottom-hole pressure (lb. per sq. in. absolute)	525

(*Continued from Page 177*)

ratios), which has been developed in Iran and is still in routine use, is based on line pressure drop, under conditions where no gas is separated above atmospheric pressure. It is only applicable in areas where the producing gas/oil ratios of all wells are known to be approximately the same and do not change appreciably over a reasonable period of time. This is the case on the Iranian fields, where the saturation pressure of the reservoir crude is known in the different areas and drops only very slowly with time. The method is purely empirical, working graphs, of which examples are shown in Fig. 2, being constructed from observed pressure and production data of a number of wells. As a routine, the flowing pressure is observed at a point 600 ft. from the atmospheric pressure end of a 4-in. production line.

On fields where reservoir saturation pressures fall fairly rapidly with production, similar graphs would require to be revised from time to time. The accuracy is, of course, dependent on the constancy of gas/oil ratio, but is quite good enough for the purpose of preliminary estimates, an error of more than ± 10 percent being unlikely if the flowing pressure is reasonably steady.

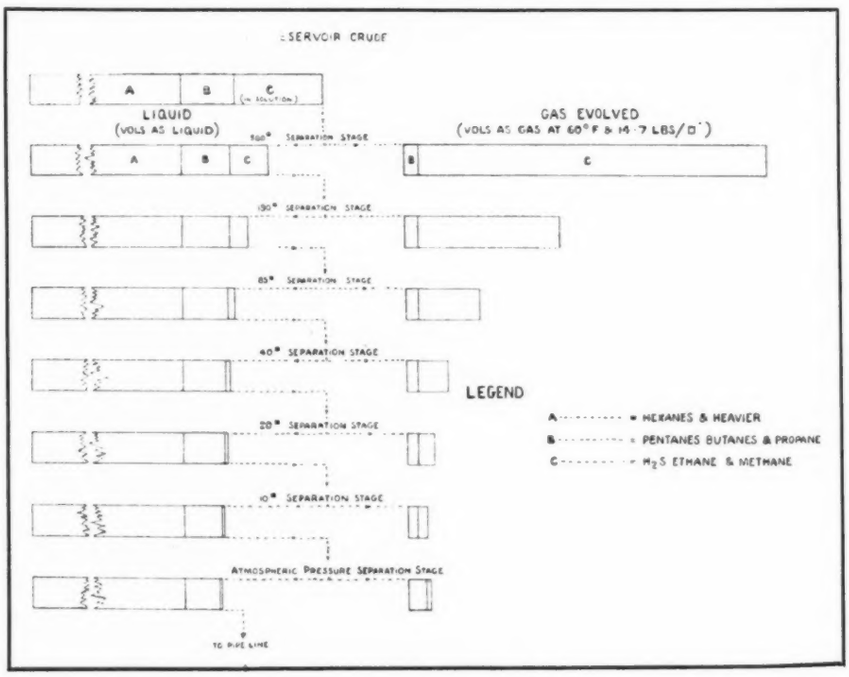


Fig. 11. Diagrammatic illustration of multiseparation process of gasoline recovery

Portable Tank and Gas Bags Method

For accurate measurement of well productions and producing gas/oil ratios at varying rates of flow, when production to individual separators or flow-tanks is impracticable or undesirable, a method has been developed and used for some years on the Masjid-i-Sulaiman field, Iran, in which the total oil and gas production of the well is by-passed for a very short time to a portable tank fitted with gas bags. Results obtained have been proved to be accurate within about ± 1.0 percent by check measurements of oil and gas productions when flowing at the same rate to full capacity tanks. This method has already been briefly described[8] by Mr. L. A. Pym, but it is thought that a more detailed description may be useful to any operators who may contemplate using similar apparatus.

The lay-out is self-explanatory from the semi-perspective sketch shown in Fig. 3, which, by the way, is roughly to scale.

Working across the sketch from the well on the right, the main points regarding equipment to which attention may be drawn before describing operating procedure are:

1. The Halliburton outfit mounted on a light truck, which is there for the purpose of lowering a bottom-hole pressure indicator into the well to a point opposite the main oil show in order that the bottom-hole static pressure with the well shut-in may be observed, and also the bottom-hole flow-

[8] L. A. Pym, *Proc. World Petroleum Congress*, 1933, 1, 452.

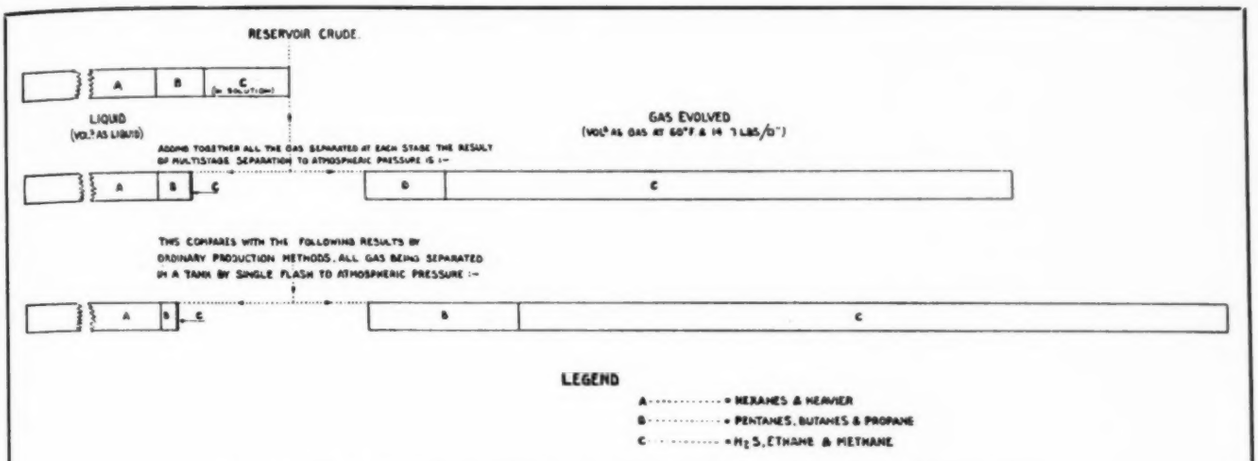

RESERVOIR CRUDE
A
B
C
LIQUID
GAS EVOLVED
THIS COMPARES WITH THE FOLLOWING RESULTS BY ORDINARY PRODUCTION METHODS. ALL GAS BEING SEPARATED IN A TANK BY SINGLE FLASH TO ATMOSPHERIC PRESSURE :-
LEGEND
A ..... = HEXANES & HEAVIER
B ..... = PENTANES, BUTANES & PROPANE
C ..... = H_2S, ETHANE & METHANE

Fig. 12. Diagrammatic illustration of extra gasoline recovery by multiseparation as compared with single flash separation

ing pressure at the different rates of flow to be tested.

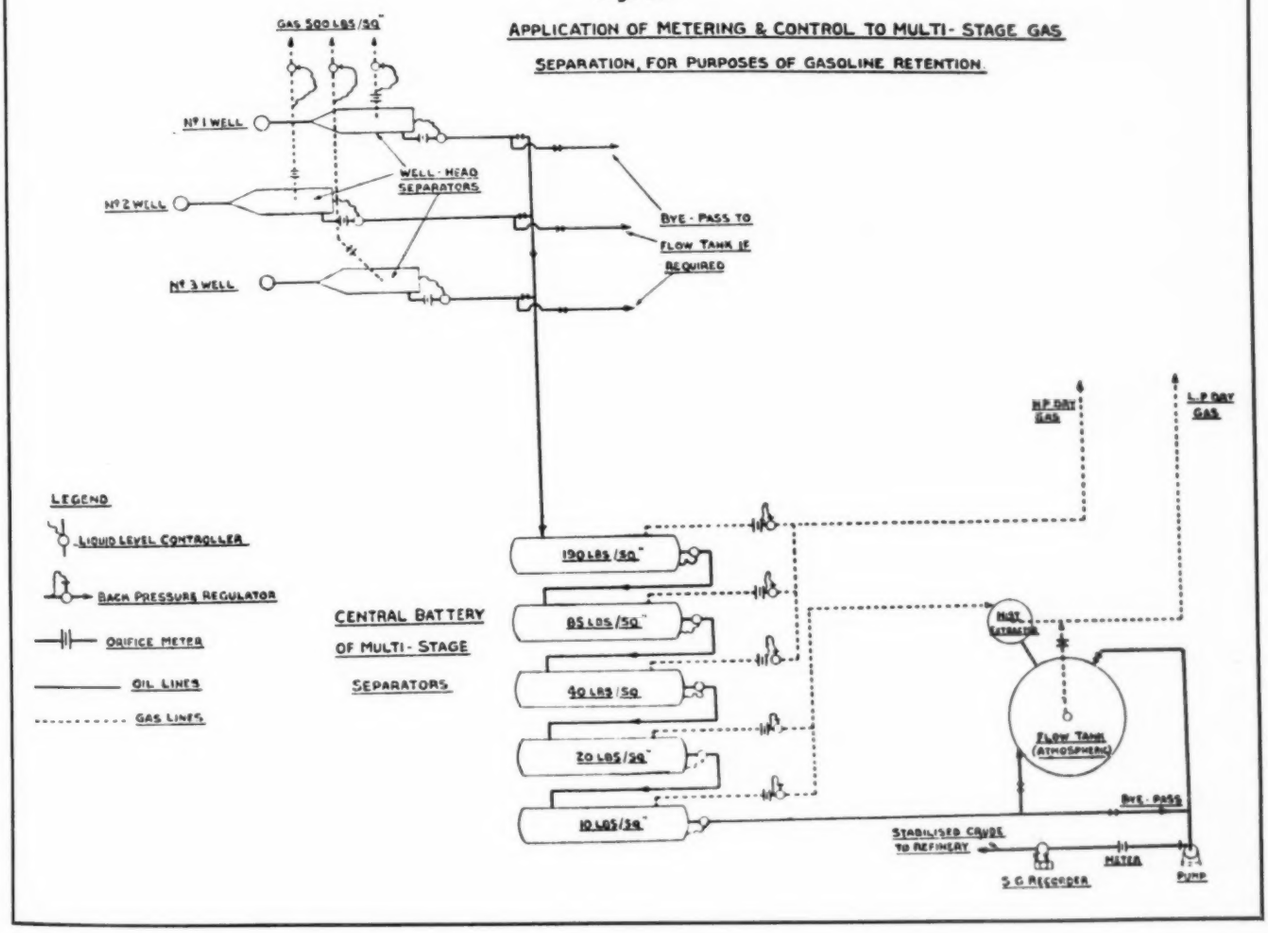
2. The removable portion of the normal production line consists of one joint that is left flanged for insertion of the special section shown in the sketch. This section, which may be inserted any time before the actual tests, includes orifice connections to the meter shown, and a Y-piece with instantaneous operating valves and setting valves for diverting flow from the production line to the tank without changing the rate of flow.

3. The orifice meter is for differential pressure readings only, in order to ensure that flow when diverted to the tank is at the same rate as when flowing in the line. If it is not, the setting valve to the tank is adjusted accordingly. The orifice plate is chosen so that at the full rate of flow there is a high reading of the meter in order that the orifice need not be changed for lower rates of flow.

While on this point, it may be mentioned that interchangeable orifice fit-

Fig. 13

APPLICATION OF METERING & CONTROL TO MULTI-STAGE GAS SEPARATION, FOR PURPOSES OF GASOLINE RETENTION.



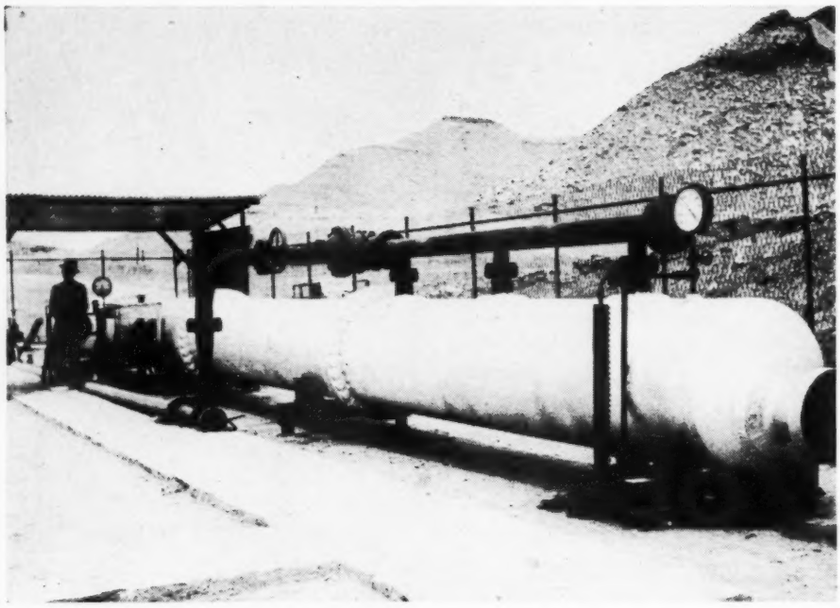


Fig. 14. Photograph of high-pressure well-head separator

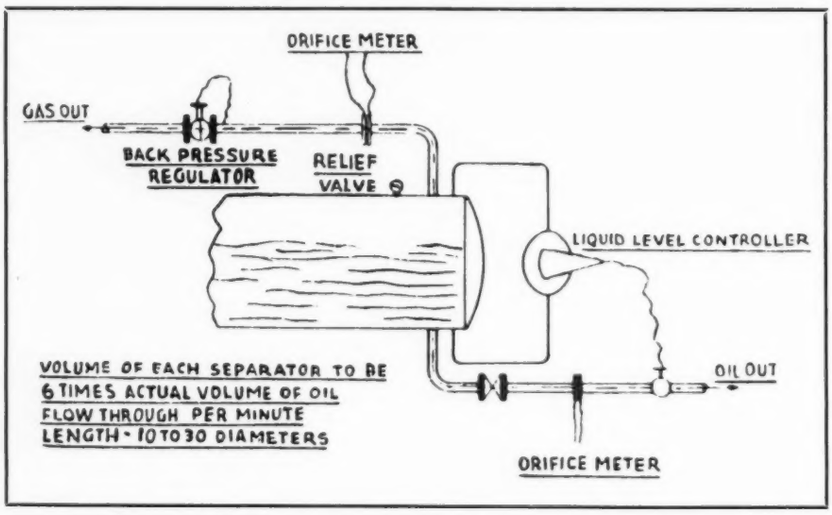

ORIFICE METER
GAS OUT
BACK PRESSURE REGULATOR
RELIEF VALVE
LIQUID LEVEL CONTROLLER
OIL OUT
VOLUME OF EACH SEPARATOR TO BE 6 TIMES ACTUAL VOLUME OF OIL FLOW THROUGH PER MINUTE
LENGTH - 10 TO 30 DIAMETERS
ORIFICE METER

Fig. 14a. Sketch illustrating metering and control on typical well-head separator

NOTE—Central battery separators are exactly similar in design, but of larger dimensions to suit throughput, and oil meter is omitted at the individual stages.

tings are now in very general use in orifice metering in circumstances where it is desirable to be able to change an orifice plate without interrupting flow. (In the Kent fitting the plate carrier can be withdrawn into an upper chamber, which is then isolated from the pipe by a cock, following which the upper carrier can be removed and the plate changed. This fitting avoids the necessity of using by-pass valves, thus saving money and space.)

4. The tank, which is permanently mounted on a trailer, complete with rectangular tank duct (24 in. by 15 in.), is about 2500 gal. capacity and about 5 ft. in height. (When not in use all tank connections, i.e., inlet, drain, and gas ducts, should be blanked off to prevent inlet of air.) The tank, and especially the 100-gal. dip tank for draining off and measuring the amount of crude delivered to the tank, should be carefully levelled before the test. A gauge glass is provided with a mark by which the initial level of the oil may be set to the same level (in the nipple above the drain valve of the main tank) before each run. If the tank were completely emptied, gas would escape with the last oil being drained for measurement. The amount of oil going into the tank, at Masjid-i-Sulaiman gas/oil ratios, is about 200 gal., this supplying sufficient gas to fill the bags.

5. The gas bags, which are of about 750 cu. ft. capacity each when inflated a reasonable amount, i.e. about 2 ft. to 2 ft. 6 in., in the middle, are made of flax canvas, 21 oz. to the square yard, double compromium proofed, wax finish. When new, each bag is treated with about 20 gal. of No. 340 lubricating oil and the upper face of each bag is treated with about 7 gal. (1 drum) after each job. the faces being reversed each time. When soaked, the bags weigh about half a ton each and roll up for transport into bundles about 5 ft. long by 3 ft. diameter. They are protected from being holed by lying on tarpaulin sheets about 30 ft. by 30 ft., the ground beneath the sheets being carefully cleared of stones. The workmen are only allowed to walk on the bags in bare feet. Loops are provided on the bags for weighting them down with pipe on the windward side.

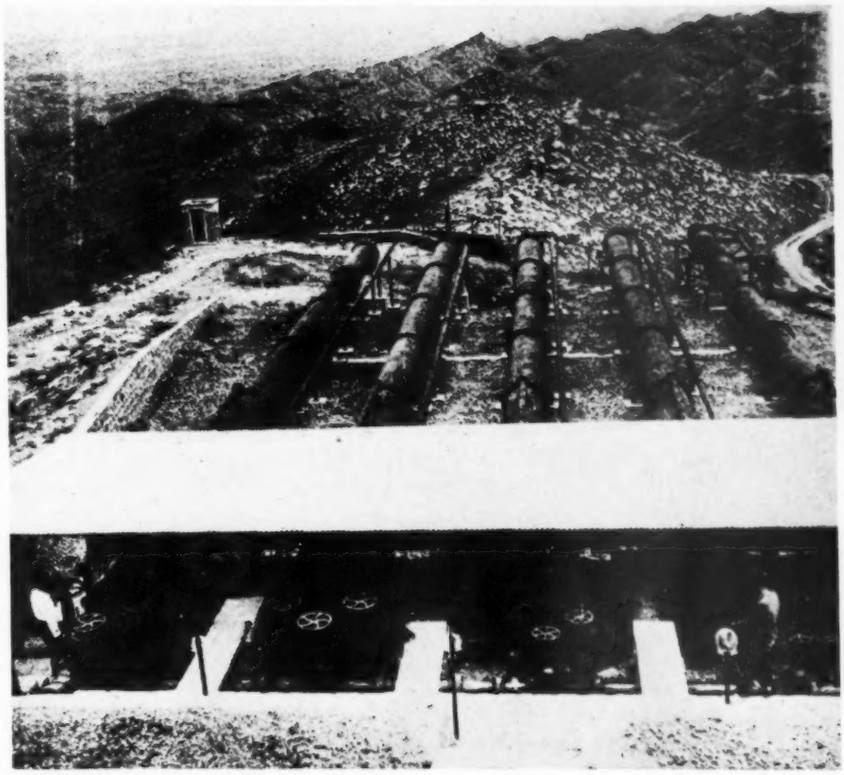
6. The throats of the gas bags are supported by a wire frame to keep them open and the necks at the end of the throats are of quadruple material with eyelet holes punched every 3 inches. The connection to the gas duct is made by means of a flange through which the throat of the gas bag is threaded, turned up, and clamped between this flange and the end flange of the tank by bolts through the eyelet holes.

7. The high-pressure gas line shown is for the purpose of operating the Korting ejector, which deflates the gas bags at a steady rate through the 2-in. evacuation line on the horizontal gas duct. During preliminary runs the high pressure gas pressure on the Korting ejector is adjusted to give the maximum rate of evacuation of the bags as indicated by the differential pressure across the orifice in the 2-in. line, which is recorded by the water manometer shown. The high pressure gas pressure required is usually of the order of 100 lb. to 150 lb., but varies according to the length and arrangement of the waste gas line. At the optimum pressure the fluctuations in the differential pressure are negligible. The exhaust line should be as straight and short as possible.

8. The manometer on the gas duct itself is to show when evacuation of the bags is complete, a partial vacuum being indicated. The T off this for sampling is in order that the specific gravity of the gas may be determined (by weighing of flash samples) and the H_2S content (or rather the acid gas content) measured in the Orsat ap-

(Continued on Page 185)

Fig. 15. Photograph of central battery of separators



(*Continued from Page 182*)

paratus shown on the horizontal duct.

Before describing the procedure of the test, attention is drawn to the photographs of the equipment shown in Figs. 4 and 8.

The procedure in any given test, after completing the hook-up and preliminary preparations as mentioned above, is:

1. With the valves on the Y to portable tank closed and well flowing at maximum rate, note the following:

(*a*) Well-head flowing pressure on both the pressure gauge and recording pressure gauge at the well.

(*b*) Line flowing pressure on both the pressure gauge and recording pressure gauge on the junction of the Y piece.

(*c*) Differential pressure on the recording orifice meter.

Wait until these are steady.

2. Close ½-in. blow-off cock between the main cock to tank and the tank setting valve.

3. Set tank setting valve at probable number of turns open for production rate to be tested—a matter of experience.

4. Close meter valves. Unroll gas bags.

5. Simultaneously open cock to tank and close cock to normal production for a few seconds and note flowing pressures on the Y-piece junction and the differential pressure at the orifice meter (opening meter valves for purpose—if they are open during actual switch there will be a kick).

6. If the flowing pressure and differential pressure have changed, adjust tank setting valve accordingly and repeat process until they are approximately the same when flowing to tank as when flowing to normal production line.

7. Run-in bottom-hole pressure indicator to main oil show and obtain readings of the bottom-hole flowing pressure and temperature at this rate of flow.

Note.—The bottom-hole pressure indicator should never be in situ in well during switches from production line to tank, as the kick may affect it unless it is at least 500 ft. off bottom. It is possible to run it in while well is flowing, except in big producers in small casing, in which case it must be started in with well shut-in.

8. While this is going on, the tank is emptied by draining to dip tank down to the mark on the gauge glass; the dip tank is emptied to within ½ in. of bottom and the gas bags are evacuated by turning on the high-pressure gas to the Korting ejector, the bags being rolled up as they deflate. During this the cock to the tank is, of course, closed. The tank setting valve is left open.

9. The first test run to the tank may then be made, the time of switching over the cocks being noted by stop-watch. Flow to the tank is continued until the gas bags are reasonably inflated (they have been unrolled again before starting the test), that is until they are about 2 ft. to 2 ft. 6 in. from ground in the middle. This takes anything from, say, 30 seconds to 5 minutes, depending on the size of the well. During this time the flowing pressures and differential pressure are again noted.

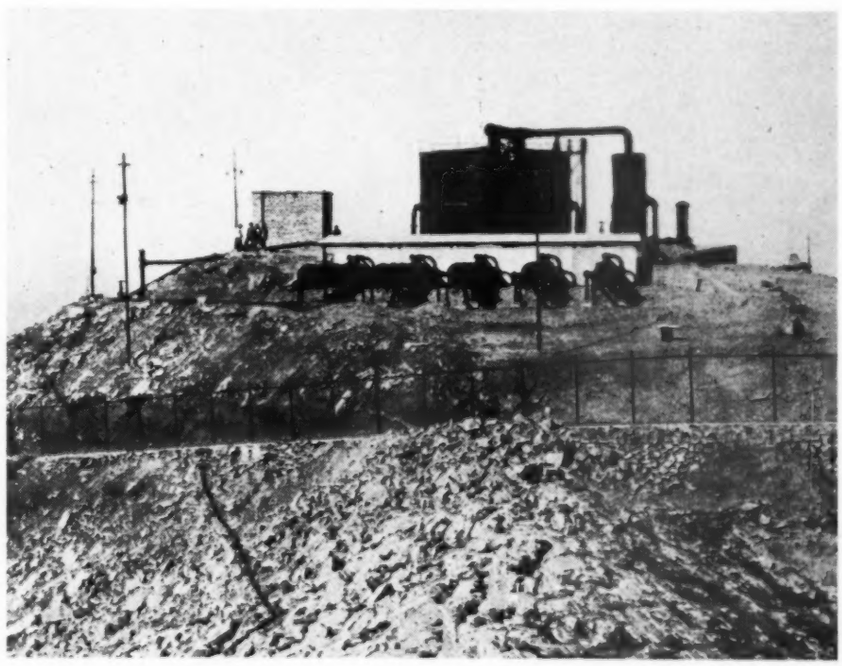


Fig. 16. Photograph of central battery and flow-tank unit

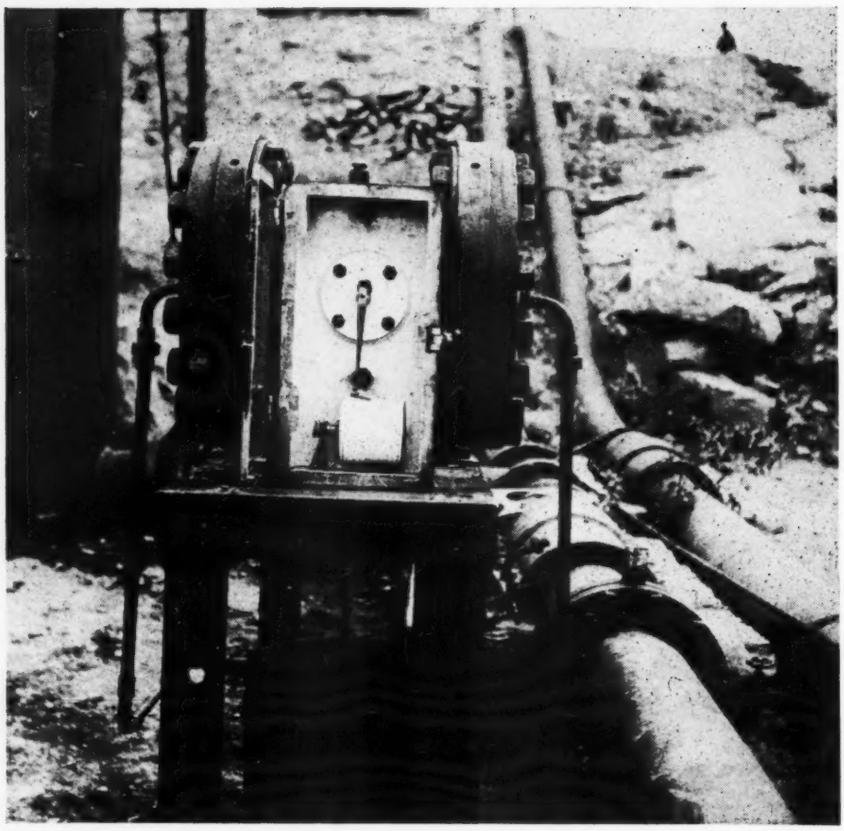


Fig. 17. Photograph of specific gravity recorder

10. Switch production back to line —noting time with stop-watch. Close tank setting valve and open the ½-in. blow-off valve between the tank cock and the tank setting valve (to prevent any gas leak from line to tank while gas bags are being deflated).

11. Open 1-in. high-pressure gas valve, ½-in. Korting ejector valve, and 2-in. cock on the gas evacuation line from the gas duct and deflate bags. Note time of beginning and end of deflation (as this is required for making bag leakage allowance later). During deflation the following observations are to be made:

(*a*) On the manometer on the 2-in. gas evacuation line—periodically—the static pressure and the differential pressure across the orifice (1½-in. orifice usually suitable), also the temperature in the line.

(*b*) Samples of gas are collected from the connection in the horizontal duct and specific gravity and H^2S content determined.

(*c*) The oil is run off and measured in the small tank (two or three fillings being usually necessary), and its specific gravity and temperature measured.

Deflation may take, on the average, about three-quarters of an hour. During deflation the well is throttled-in in preparation for the next test at a lower rate of flow.

12. All tests are repeated at approximately two-thirds full flow (as determined by the differential pressure on the recording orifice meter) and at a lower rate of flow in order to give a point near the top of the steep portion of the flowhead-pressure production curve. (They are done in this order because the bottom-hole pressure indicator is a maximum reading instrument.)

13. After making the last test, it is repeated, but the gas bags are not deflated until next day. The gas/oil ratio determined next day is less, on account of bag leakage, and, the exact period of standing being known, this difference is applied on a proportionate basis to correct the actual gas/oil ratios determined for the slight leakage during deflation in the actual tests.

14. The well is closed-in and the static bottom-hole pressure and temperature are measured with the bottom-hole pressure indicator. A bottom-hole sample taker is then run and two bottom-hole pressure samples collected for determination of the saturation pressure and dissolved gas content of the reservoir crude, the latter being compared with the producing gas/oil ratios measured.

15. All pressure gauges and recording pressure gauges are calibrated against a dead weight tester over the range of observations made. Barometric pressure on each day is observed and the ground elevation of the well noted for use in calculations converting gas volumes to standard conditions.

From the data described above, all the information required from the well can be calculated. Taking the minimum period of test as about 30 seconds (at least 1 minute is desirable to attain the accuracy mentioned of ± 1 percent) the tank and bags are capable of handling a gas production of about 4000 cu. ft. per day, which, at Masjid-i-Sulaiman gas/oil ratios, represents about 600,000 gal. of crude a day, the crude-rate capacity varying, in different fields, of course, with the producing gas/oil ratio. Larger capacity apparatus could be made on the same principles, but that described is approaching the limits of convenience in handling and transport.

The type of data obtained is illustrated in Figs. 9 and 10.

This paper is hardly the right medium in which to discuss the significance of these data. Attention may, however, be drawn to one point, the steepness of the (lower) curve relating bottom-hole differential pressure (the difference between bottom-hole static pressure and bottom-hole flowing pressure) in the smaller well, as compared with its flatness in the larger well. This indicates that the comparatively small production capacity is due to poor reservoir connection and not to lack of available energy in the reservoir crude. In such circumstances acid treatment is indicated as desirable and has frequently been successful in converting a well of characteristics shown in Fig. 9 into one of characteristics shown in Fig. 10.

Metering in Multistage Gas Separation Process of Gasoline Recovery

Coming now to the metering of "live" crude in multistage gas separation: before discussing detail it may be advisable to describe in general terms this rather novel system of gasoline recovery, or, rather, retention. The physics and mathematics of the process have been dealt with by Dr. C. J. May in a paper[9] before the World Petroleum Congress in Paris last summer, but so far only the synopsis would appear to have been printed. (Dr. May with Mr. H. S. Gibson, assistant fields manager (Production) in the Iranian fields, was responsible for developing this process, which has been in operation on the

[9] C. J. May, *Proc. World Petroleum Congress*, 1937, Section 1.

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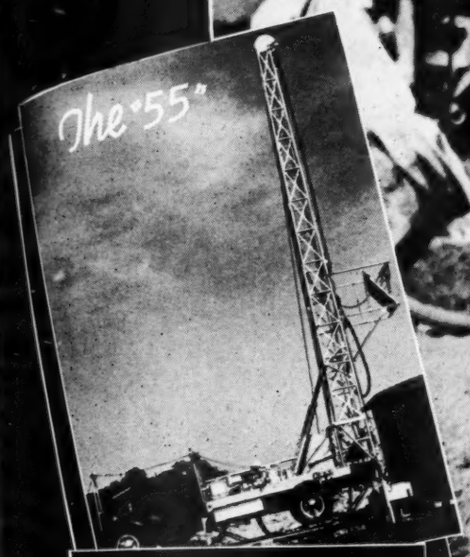

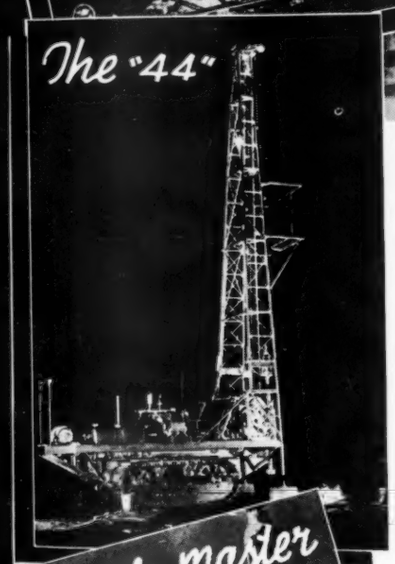

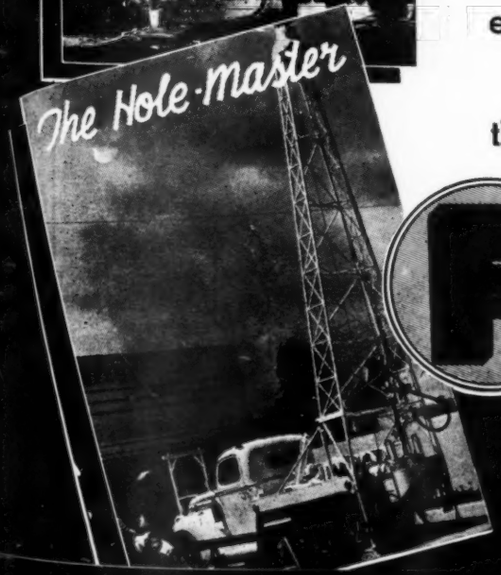

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Haft Kel field since 1930.) The underlying principles may, however, be stated reasonably briefly.

The objective is to retain in the liquid phase in the flow tank crude delivered to pipe-line the maximum proportion possible of the gasoline components of the reservoir crude, these remaining, of course, entirely in the liquid phase until the pressure of the reservoir crude is reduced below its saturation pressure at any given temperature.

It is an established fact—and there is, therefore, no need to enter into the theoretical reasons for it—that as the pressure of the reservoir crude is lowered below its reservoir saturation pressure, e.g. by flow in a well, the lighter hydrocarbons, methane and ethane, invariably constitute the bulk of the gas coming out of solution at the higher pressures. The proportion of lighter hydrocarbons in the gas evolved progressively decreases and the proportion of potentially useful "gasoline" components, propanes (? useful), butanes, and pentanes, progressively increases as the pressure of the crude is reduced, the increase being very rapid as atmospheric pressure is approached. ("Gasoline" is used in a general sense. Actually it is an elastic term.)

Now, for a condition of equilibrium to be reached at any pressure between crude and gas with which it is in contact, e.g. in a separator or in a tank, the partial pressure of each individual component—let us in future consider, say, butane only—in the liquid phase, must equal the partial pressure of that component in the gaseous phase, and, until such equilibrium has been reached, the butane will continue to come out of solution from the crude, thereby robbing the crude of some of its potential gasoline content. Once equilibrium has been reached, the crude is stable for those particular conditions of pressure and temperature as long as it is in contact with the same gas.

The actual amount of butane that is required to be evolved from the crude to build up the butane partial pressure in the gas space is, however, greatly reduced if the proportion of butane in the total gas already in contact with the crude has been increased by previous removal of lighter hydrocarbons at a higher pressure stage of separation.

The reason for this is that the partial pressure of the butane in the gaseous phase, being the actual pressure of separation $\times$ the percentage by volume of butane in the total gas (making the necessary allowances for deviations from Boyle's Law), is very considerably affected by removal of other constituents of the gas in earlier stages of separation; whereas the partial pressure of the butane in the liquid phase, being the vapor pressure of butane at the temperature of separation $\times$ the mol fraction of the butane in the crude, would be constant for any given pressure and temperature of separation, were it not for the extra retention of butane in the crude, resulting from the process.

The same process is repeated at each successive pressure stage of separation until atmospheric pressure is reached, the net effect being a stabilized crude (providing, of course, it is in contact with its own flow tank gas), which is of lighter gravity and contains more gasoline than single flash crude.

The process may, of course, be completed at a higher pressure than atmospheric pressure—say 10 lb. gauge—in which case gasoline retention is greater, but the crude must be retained at that pressure through the pipe-line and until actually handled in the refinery.

A simple non-technical way of explaining the process is to visualize a well as producing neat gasoline only with a large quantity of air. It is easy to see that if one were to separate the bulk of the air at high pressure much less gasoline would evaporate than if the air were delivered to the tanks.

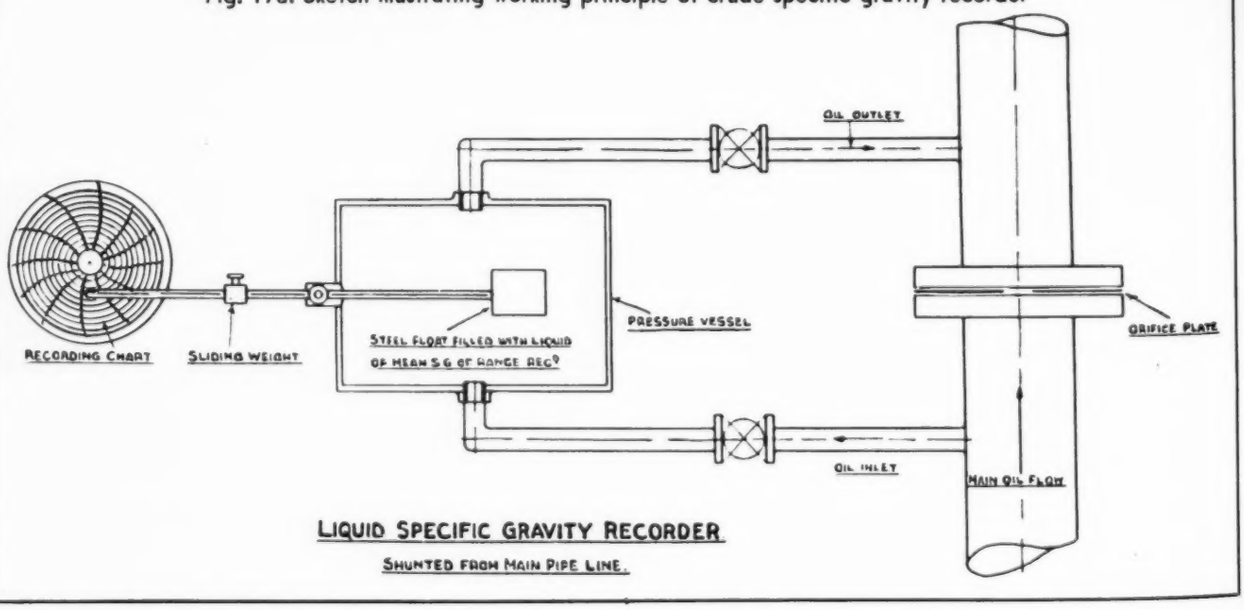
The diagram (Fig. 11) illustrates the process and results obtained.

It will be noted that the bulk of the methanes and ethanes are removed in the first two stages of separation. A point to which attention should be directed is the decrease in liquid volume of the crude at each separation stage, as this has to be taken into consideration in the metering. This point will be returned to later.

The diagram (Fig. 12) illustrates the increased recovery of gasoline constituents by multistage separation as compared with single flash production to tank at atmospheric pressure. Gasoline, being an elastic term, is not specifically referred to as such, Fig. 12 showing the retention of grouped constituents.

The increased volumetric production of crude in the case of multiseparation will be noted, the increase being mainly represented by pentanes, butanes, and propane. The large reduction in producing gas/oil ratio will also be noted. A point that should be appreciated is that, although in Fig. 12 the comparison is made at atmospheric pressure, the multistaged crude can be

Fig. 17a. Sketch illustrating working principle of crude specific gravity recorder



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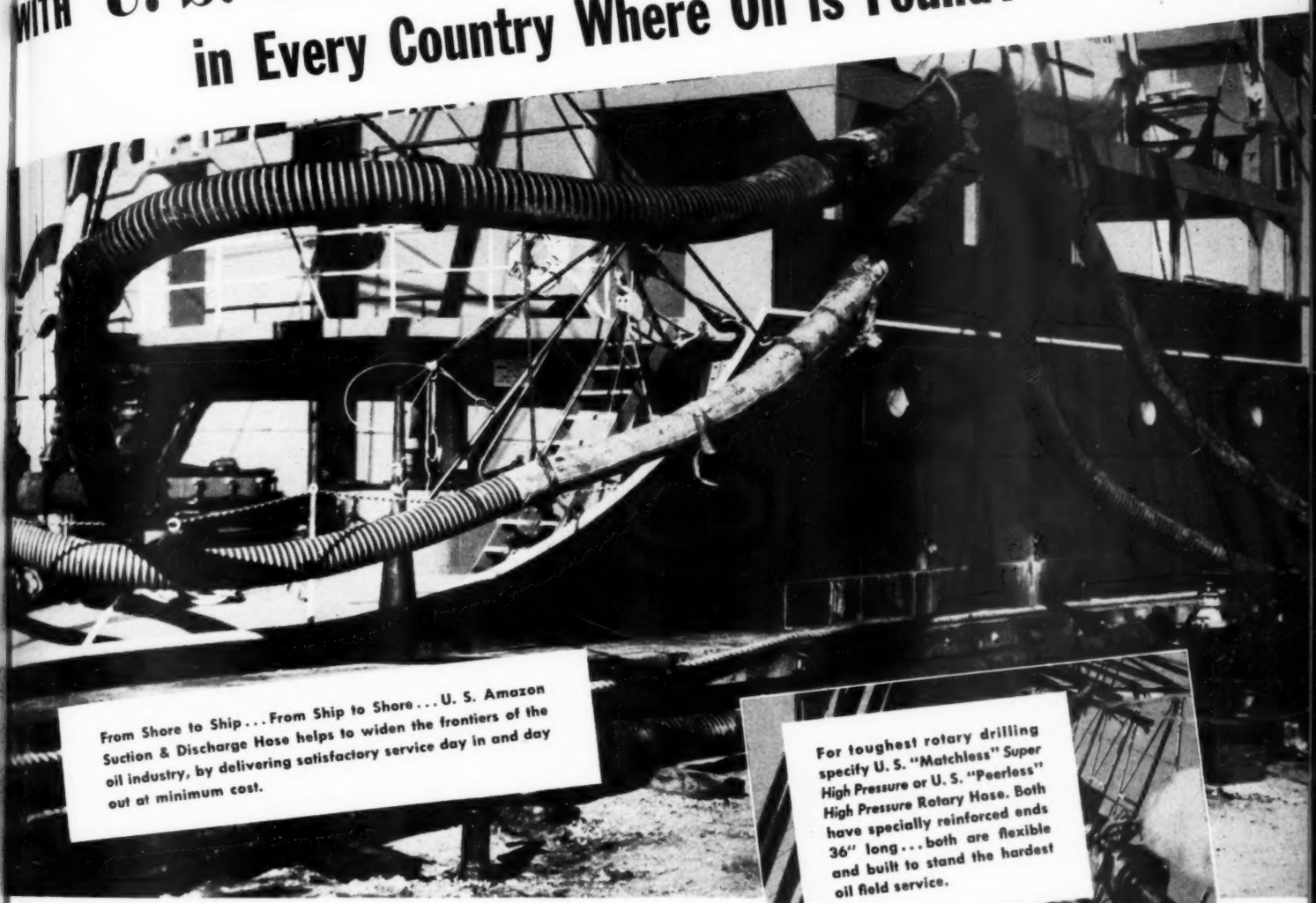

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delivered direct to pipe line from the 10-lb., or even the 20-lb. separators, thus delivering an even greater proportion of pentanes, etc., to the refinery. By multistaging to 10 lb. the extra retention of gasoline components is of the same order as the recovery obtained by processing the whole of the single flash gas production in 35-lb. absorption plants.

Fig. 13 shows the general layout of a multiseparation scheme and illustrates the use of meters and automatic control equipment. The sketch is self-explanatory, but certain points having a bearing on metering may be brought out:

1. Crude production from the individual wells can only be metered at the well-head separators (at the outlet of course) as it passes thence to the central battery. At the well-head separators, as will have been noted from Fig. 11, the actual liquid volume is substantially greater than it is by the time it reaches the communal metering point on the pipe line after reduction to atmospheric pressure. The communal total and the sum of the individual totals, therefore, require to be reconciled.

2. The gas off the separators is metered at the pressure of the separators for greater accuracy. Allowance must, therefore, be made for deviation from Boyle's Law, which is considerable.

3. The object of the various metering operations is, in combination with analyses of the gases and crude at the different stages, to enable a balance sheet to be drawn up, on the lines of diagrams Nos. 11 and 12, thus ensuring maximum efficiency of operation.

4. The multistaged crude is not suitable for tank dipping except in pressure tanks, as a proportion of the extra gasoline constituents retained by the process would be lost by evaporation. It is, therefore, preferable to meter the multistaged crude. Consequently, to avoid pulsation and ensure accuracy in metering, centrifugal pumps should be used for delivery to refinery rather than reciprocating pumps.

5. A continuous record of the specific gravity of the crude piped to refinery is essential, as a reduction of more than 1½ percent in specific gravity may be practicable by multistaging to 10 lb. instead of single flashing to atmospheric pressure.

Figs 14-17a are of interest in connection with the points generally discussed above.

A small proportion of the flow in the pipe line is shunted through the pressure vessel of the recorder, inside which is a float filled with a liquid of the mean specific gravity of that to be recorded. The actual weight of the float is balanced by a sliding weight. The vertical movements of the float are recorded on the chart by the pivoted arm, which works through a gland.

This instrument, though rather outside the range of metering in the ordinary sense, is the most important one in the process of multiseparation as being a direct indicator of the efficiency of extra gasoline retention.

In the course of solubility experiments in 1926 the author noted and recorded that the specific gravity of crude that had been reduced to atmospheric pressure by slowly bleeding off gas from a 1500-lb. well-head sample was appreciably less than that of the crude normally being produced on the field in question. The commercial significance of this phenomenon was not, however, appreciated at the time and it was not until 1929, as a result of Messrs. Gibson's and May's investigations referred to earlier, that multistage separation was recognized to be a practical oilfield process of gasoline recovery, being adopted on the Haft Kel field in 1930.

Independently in the United States, Lindsley,[10] also working on well-head pressure samples in connection with solubility experiments, had obtained similar results, the specific gravity of his samples, after gradual evolution of gas content to atmospheric pressure, being appreciably less than that normally obtained by operators on the Kettleman Hills, Ventura Avenue, and Oklahoma City fields.

[10]B. E. Lindsley, *Trans. A. I. M. M. E.*, 1931, Petroleum Division, p. 252.

Oil Production in Germany Shows Decline

GERMANY'S production of mineral oil showed a small but steady decline during recent months. Information obtained from the Amtliche Preussische Pressedienst indicates that the decrease occurred largely in the Nienhagen-Hänigsen fields. Production in this field decreased by 12,257 bbl. as compared with May, 1938, but increased by 12,243 bbl. or approximately six percent compared with June, 1937. The production of mineral oil in the Province of Hannover during the first six months of the current year increased by about 12 percent over that of the corresponding period of the preceding year.

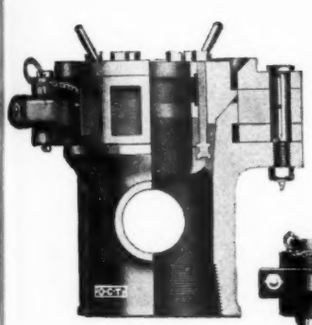
Accordingly, production in the Nienhagen-Hänigsen fields increased by approximately 17 percent, while decreases of about four percent and 17 percent, respectively, are shown in the Wietze-Steinförde and Eddesse-Oberg fields during the same period.

Total production of mineral oil in Germany during the first six months of 1938 amounted to 1,899,450 bbl. as compared with 1,491,588 bbl. during the corresponding months of 1937, an increase of approximately 27 percent. Hannover fields accounted for about 81 percent of total production, as compared with 93 percent during the first six months of 1937. Production during the first half of 1938 averaged 316,575 bbl. per month, compared with 264,446 bbl. during the preceding year.

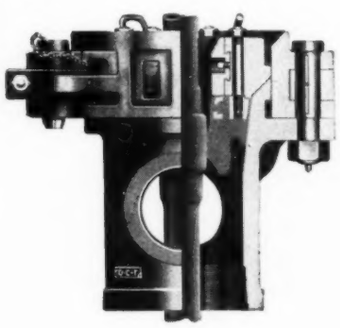
Compared with Germany's consumption of mineral oil products, the domestic production constitutes only a very small percentage. During 1937, the consumption of gasoline amounted to approximately 17,500,000 bbl., and it is stated that consumption during the current year will exceed 21,000,000 barrels. The domestic production of synthetic gasoline is reported to constitute approximately 60 percent of present requirements.

Rumania supplies some of the oil imported into Germany, but the Rumanian Government has placed a quota on oil exports, which compels Germany to draw its supplies from other sources as well. It is reported that barter transactions have recently been concluded between Mexico and Germany.

Just to be [redacted] sure



Left: Sectional view of an O-C-T type "D" Blowout Preventer equipped with regular packoff rubber, which permits rotating and raising and lowering of pipe the length of one joint.



Right: Sectional view of an O-C-T type "D" Blowout Preventer equipped with stripper rubber, which passes pipe collars yet effectively seals in well pressures.

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The Application of Automatic Control to Refinery Process Operations*

By S. W. ADEY, B.Sc., A.R.C.S., F.I.C. (Associate Member)

SYNOPSIS

The paper opens with a brief description of the more important types of process control instruments and their underlying theory. The selection of methods of control and the installation of instruments are next discussed and the importance of close coöperation between plant operator, designer, and instrument manufacturer is emphasized.

Stabilizing and Automatic Re-Set Devices and their significance in the control of continuous processes are explained.

Finally the economic aspects of the subject are reviewed, emphasis being laid upon the fact that whereas some instruments definitely improve operating efficiency and quality of product, others serve purely as labor-saving devices. The paper concludes with a note on the organization of instrument repair services.

INTRODUCTION

MOST petroleum refinery processes are nowadays carried out continuously, and the work of operation consists largely in holding at a predetermined value certain physical conditions of pressure, temperature, flow rate, and liquid level. These physical conditions then serve to ensure the proper functioning of the plant, whether the process itself be physical or chemical, so that products of constant quality are obtained.

Automatic control may be applied to certain batch operations, but the field is wider if the process is continuous, so that modern, continuous plant has fostered the demand for such devices. Instrumentation is, therefore, comparatively new, and only in the last ten or twelve years has it been able to show any real saving in labor. For such a saving to be achieved it is necessary for the work of instrument maintenance to be reduced to a reasonable figure, and also for the instruments themselves to be thoroughly reliable. There must be no need for "stand-by" operating labor in case of failure.

Labor-saving is not, however, the sole purpose of automatic control. Manual control of certain operating conditions, *e.g.* cracking still pressure, cannot be made as effective as automatic control, so that solely on the grounds of operating efficiency and constant quality of product, there may be a case for dispensing with the human element. This part of the subject will be dealt with more fully later on.

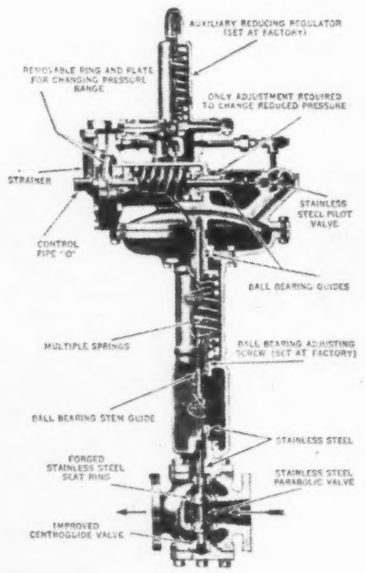
In the design and installation of control instruments it is very easy to be ingenious, but much more difficult to be practical. Such equipment is at present passing through very much the same stages as did the accessories in motor-cars a few years ago, by which it is meant that even today a piece of refinery plant may be designed and built, and then the instruments added as an afterthought. Until instruments come to be considered as much an integral part of the plant as, say, the pumps, they will justify as much criticism as did the motor-car accessories.

It is only during the last four or five years that instrument-makers have obtained a real grasp of the processes for which they were trying to build control gear, and the value of what knowledge they have gained is already showing up in more efficient and reliable equipment. It must be realized that the control of any given physical condition, such as temperature, is a different problem on every kind of plant, and no one fixed type of instrument can possibly meet every requirement efficiently.

The first and second parts of this paper cover a description of the basic types of control instrument used in petroleum refineries and their application to specific problems. It is not intended, neither is it possible, to describe all the better-known makes and types, and where particular ones are mentioned, this is purely by way of illustration.

The third part of the paper deals with the economic aspect of applying automatic control, and is intended mainly for those who require guidance in deciding, as a matter of policy, whether automatic control should be adopted or not. This subject has been dealt with last, not because it is considered less important, but because some understanding of the technical aspect is a help in reaching a decision.

Fig. 1. Modern type of gas-pressure regulator. (By permission of The Crosby Valve and Engineering Company, Ltd.)


AUXILIARY REDUCING REGULATOR (SET AT FACTORY)
REMOVABLE RING AND PLATE FOR CHANGING PRESSURE RANGE
ONLY ADJUSTMENT REQUIRED TO CHANGE REDUCED PRESSURE
STRAINER
STAINLESS STEEL PILOT VALVE
CONTROL PIPE "O"
BALL BEARING GUIDES
MULTIPLE SPRINGS
BALL BEARING ADJUSTING SCREW (SET AT FACTORY)
BALL BEARING STEM GUIDE
STAINLESS STEEL
FORGED STAINLESS STEEL SEAT RING
STAINLESS STEEL PARABOLIC VALVE
IMPROVED CENTROGUIDE VALVE

1. Theory and Basic Types of Instrument

All instruments consist essentially of two parts: first that which measures the physical condition to be controlled, and secondly that which does the controlling. The second element is often so attractively ingenious that one is likely to ignore the first, wherein most of the difficulties of the problem may reside, because it is there that the closest cooperation between instrument-maker and plant-designer is required. For this reason, each basic type of instrument will be considered as consisting of the above two separate items.

(i) *Gas-Pressure Controllers*

These are used for maintaining a constant pressure in natural gas plants, stabilizer columns, cracking still columns, etc. The earliest type consisted of a double beat-valve held in the open or closed position by means of a weight and lever, and actuated by means of a diaphragm upon which the gas pressed. Insofar as a simple weight and lever is a very poor pressure-measuring device, just so far was this type of controller inadequate.

A spring was soon substituted for the weight and lever and, even today, where close control is not required this type is still seen. So simple a mechanical contrivance, however, lacks sensi-

(*Continued on Page 195*)

*Paper presented for discussion at the One Hundred Seventy-ninth General Meeting of the Institution of Petroleum Technologists (now The Institute of Petroleum) held on January 11th, 1938.

(*Continued from Page 192*)

tivity, because the force required to overcome mechanical friction is too large in comparison with that resulting from a small change in gas pressure on the diaphragm. Just as with motor-car brakes, some form of servo motor or its equivalent is necessary.

To illustrate some of the important advances that have taken place in the last few years, a modern type of gas-pressure controller is shown in Fig. 1, the main features of which are as follows:

(*a*) The main controlling valve is actuated by air, which is supplied to the instrument at a constant pressure, usually 25 lb. per sq. inch. The gas pressure to be controlled is admitted to a small diaphragm, to which is attached an air valve, more or less air being thereby admitted to the main diaphragm as the gas pressure changes. The rate at which air is admitted from the constant-pressure supply to the main diaphragm depends on the gas pressure, but as there is also a steady leak-off to atmosphere from above the main diaphragm, the pressure on it will not change unless the rate of supply differs from the rate of leak-off. Now, the physical dimensions of the gas-actuated air-valve are fixed, whereas the leak-off is manually adjustable, so that the sensitivity of the instrument can be varied by changing the rate of leak-off. Thus the separation of the measuring device, *i.e.* the smaller gas-actuated diaphragm and spring, from the controlling device, which is the main valve and diaphragm, enables the characteristics of the instrument to be varied somewhat to meet individual conditions. For example, a vessel the pressure of which it is required to control may be receiving gas in small bursts; either the pressure may be held quite constant by adjusting the controller to eliminate the gas in corresponding small bursts, or else the pressure in the vessel may be allowed to vary between narrow limits and the gas let off at a fairly steady rate. If it is desired to meter the outgoing gas on a recording meter and obtain a readable flow-chart, the latter will be preferable. In the particular case cited above, where the gas supply to the vessel is fluctuating rapidly, it is important to bear in mind that no controller could maintain a perfectly steady pressure and at the same time a meterable outflow; this point is often lost sight of by operators who expect what is, in effect, a physical impossibility unless the vessel is very large in comparison with the fluctuating input. The ability to provide an easily meterable flow rate is still further enhanced by employing stabilizing and damping devices, to be described later.

(*b*) To reduce friction, all important moving parts are on grease-packed ball-bearings, and the main spindle passing through the stuffing-box is very thin.

(*c*) The seats of the main double-beat valve are parabolic in shape, and not merely the conventional bevelled mushroom type. This gives much better flow control at small openings. Other devices, such as the V-ported cylinder, are equally effective.

(*d*) The rubberized diaphragm on which the gas presses is covered with a layer of oiled silk to resist the effect of hydrocarbon gas, but even so it may be advisable to interpose a liquid seal between this diaphragm and the gas, further to reduce the risk of the latter being rotted away.

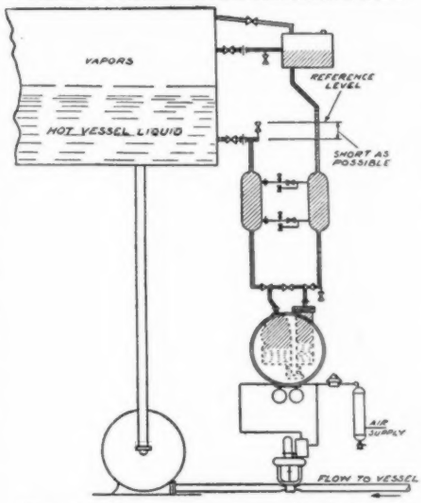


Fig. 2. Manometer type liquid-level controller. (By permission of Messrs. Foxboro-Yoxall, Ltd.)

(ii) *Liquid-Level Controllers*

As with the pressure controllers described above, the controlling item is a spring-loaded diaphragm valve of the balanced, double-beat type, air being the operating medium. Valves directly controlled from a float through a mechanical linkage are not usually so satisfactory, and suffer the further disadvantage that the control valve must be placed close to the vessel in which the liquid level is to be held steady.

Particularly in the case of liquid-level controllers is the level measuring unit of prime importance. Two types are in common use: the ball float and the mercury manometer. The ball-float variety takes two forms: either with the float in a separate small vessel termed the "kidney" or with the float right inside the main receiver or column base. Floats are likely to puncture or be crushed when the vessel is being pressure-tested, so that the latter type should not be used unless occasion demands, *e.g.* when controlling thick tar. Where a "kidney" is used, this is connected to the main vessel by two 2-in. lines fitted with block valves to enable the float to be isolated and changed if necessary. By this means also any swirl in the main vessel is rendered less likely to affect the position taken by the float. The float arm rotates a spindle that passes through a gland in the "kidney." The partial rotation of this spindle is made to control the supply of air from a constant-pressure source to the diaphragm of the control valve, and so regulate the level. If the liquid being controlled is under pressure, it is possible that the float spindle will be subjected to end thrust on that account, and unless there is an effective ball-thrust race to take this, excessive friction will result, to the detriment of proper working of the instrument.

The second type of liquid-level measuring device is the mercury manometer in the same form as used in orifice meters. In this case one arm of the manometer is connected below the liquid level and one above, so that the meter pen arm records the change in liquid head. The pen arm or its equivalent then operates an air relay in a similar manner to the float spindle in the first type. (Fig. 2.) If liquid is entering a vessel in short bursts, it is quite impossible for a level controller on the outlet to maintain both a steady level and a steady, meterable outflow; one or the other must be allowed to vary. The manometer type of level controller is very suitable for dealing with such cases, as it can be designed to allow the level to swing quite a lot while it maintains a reasonably steady flow, and so permit metering of the liquid stream. Generally speaking, it is not quite so suitable for the control of heavy, hot-tar levels as the internal-float type.

(iii) *Flow Meters and Flow Controllers*

By far the most popular type of flow meter is the orifice meter. (Fig. 3.) In this instrument the difference in hydrostatic head put up by an orifice inserted in the fluid stream is impressed on a mercury manometer, which, *via* a steel float, operates a pen arm on a circular chart. Where gas under pressure is being metered, a second pen arm records the static pressure simultaneously on the same chart.

It is not the purpose of this paper to discuss metering in detail, as this is a very broad subject, but one or two points may be mentioned. The commercial types of orifice meter should not be expected to measure pulsating

flow with accuracy, hence steps should be taken in the design of the plant to see that flows do not pulsate. The second point is that, in the cases of hydrocarbon gases under pressure, allowance must be made for the deviation from Boyle's Law where calculation shows this to be necessary. Thirdly, orifice meters will not give accurate results where the flow is in the viscous region unless special corrections are applied. In practice it pays to avoid such conditions, because the correction factors are seriously influenced by temperature and quality of the liquid being metered.

There are on the market a number of displacement meters that can be used for viscous liquids, but the fact that they do not measure the instantaneous rate of flow is often a disadvantage from the operators' point of view.

The flow controller is an adaptation of the orifice meter in which the pen-arm mechanism is made to operate a diaphragm valve on the metered stream *via* an air relay. (Fig. 4.) In this case the mercury manometer operates an inductance bridge system, so that the differential pressure is transmitted to the recorder electrically. This recorder then operates the air relay to the diaphragm-type flow-control valve, so that if the metered stream tends to change in flow rate, the control valve checks it.

(iv) *Temperature Controllers*

Temperature controllers operate in a variety of ways, but the two commonest types, which cover most requirements, employ vapor-pressure bulbs and electrical pyrometers, respectively, as the measuring devices. In the latter case certain makes are entirely electric, in that the pyrometer is caused to relay one or more electric motors, which operate valves on the heating-medium supply.

Those temperature controllers in which the temperature measurement is obtained by the change in vapor pressure of a liquid in a bulb invariably use air as the main controlling medium. The pressure in the heated bulb causes a bellows or Bourdon tube to expand or contract, and this in turn controls the air supply to a diaphragm valve on the fuel or steam supply. These instruments are quite suitable for temperatures within the range of the measuring device, but for higher temperatures, *e.g.* cracking still outlets, the pyrometer type is advisable.

A very modern example of the latter type, employing a potentiometer-type pyrometer actuating, in this case, an air relay is shown in Fig 5. This instrument, which is typical of up-to-date air-relay practice, operates as follows:

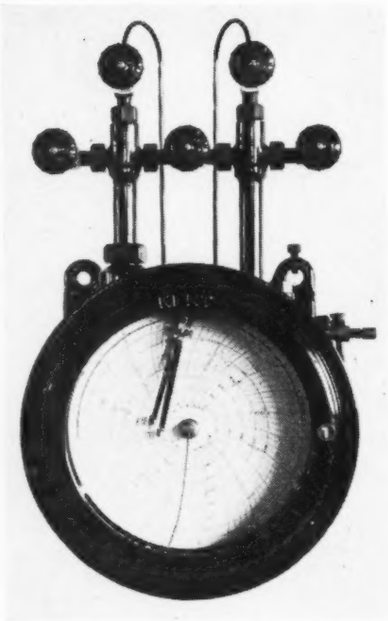


Fig. 3. Orifice meter for oils or gas. (By permission of Messrs. George Kent, Ltd.)

The rotation of the slide-wire disc, which is a measure of the temperature, opens or closes a flapper valve on a restricted air supply to the diaphragm of the burner gas or steam-control valve, thus causing this valve to increase or decrease the supply of heating medium. To stabilize the system, *i.e.* to avoid hunting, there is a second control of air pressure to the valve diaphragm. This is effected by taking a pressure lead from the burner gas or steam main after the control valve, and causing this to operate the flapper valve on the air supply in the opposite direction to the slide-wire disc, but to a lesser extent. Some such device is essential in the case of, say, a pipe-still outlet temperature controller, where the time taken for a reasonable increment in burner gas flow to affect the temperature measured is considerable. Stabilizing devices are discussed generally in a separate paragraph, because in a large continuous plant they are of supreme importance.

The above brief description of the four main types of controllers, pressure, level, flow, and temperature, suffices for the purpose of this paper.

II. Technical Considerations in the Application of Automatic Control

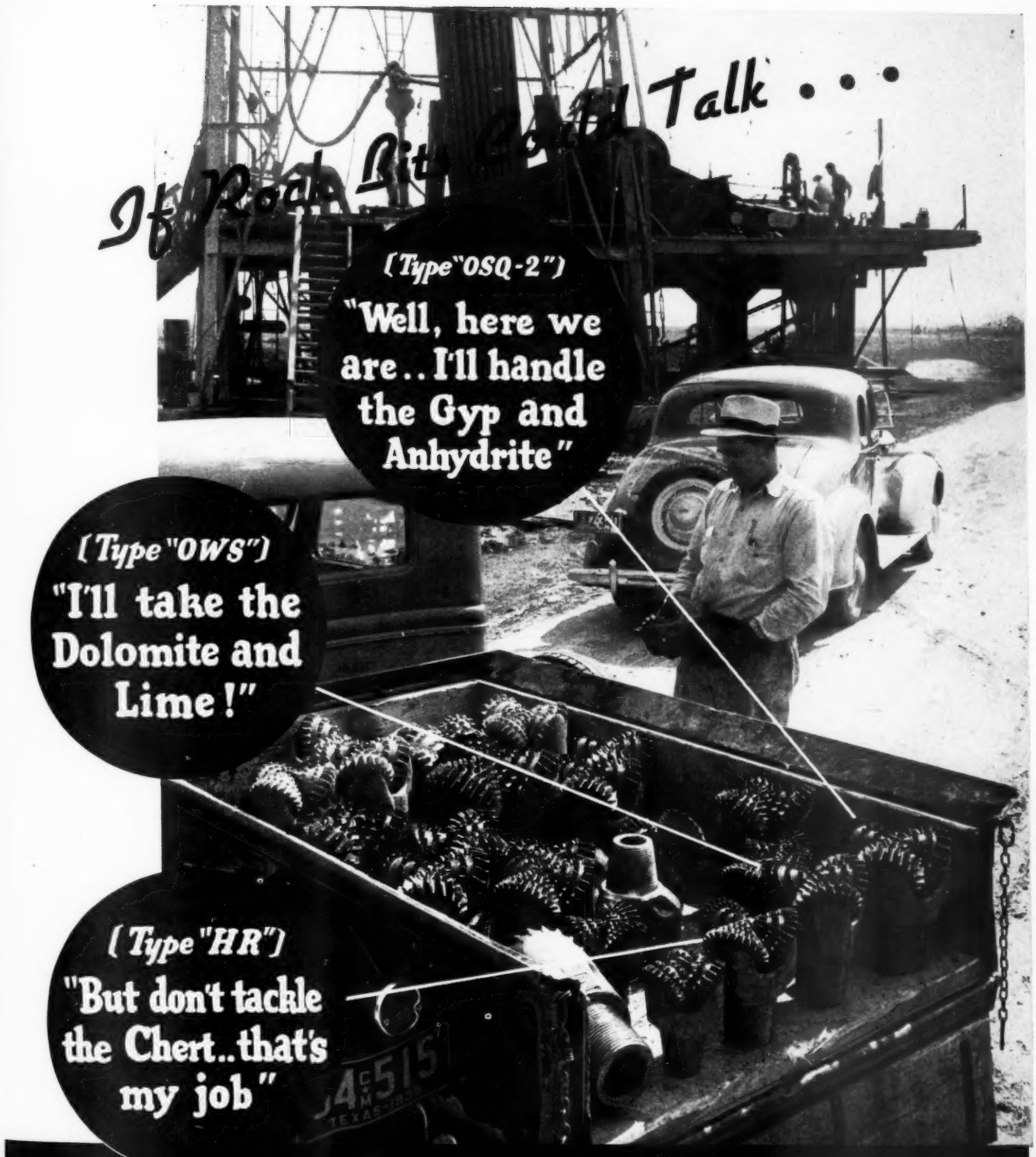
This aspect of the subject will be considered under three headings—Selection of the Conditions to be Controlled, Selection of the Point of Control, Time Lag and the Stabilization of Controllers.

(i) *Selection of Conditions to be Controlled*

In the first case, let us consider a crude-oil distillation unit. If a column is operating at constant pressure and receiving a constant-quality feed, then the quality of distillate taken either as overhead or side streams will vary if any of the following are changed: reflux ratio, temperature at point of off-take, or quantity taken-off. The reflux ratio determines the closeness of the separation and, if all the distillate is taken overhead, a reflux ratio controller (two interconnected flow controllers) will fix this. In these circumstances, so long as the feed and the feed temperature are constant, this instrument alone will ensure a constant-quality overhead and residue, more or less independent of the rate of feed up to the capacity of the column. If, however, side streams are taken off, this instrument is less effective, and we are left with either quantity or temperature as the useful control conditions. If a crude of constant quality is being distilled, experience shows that, as far as side streams are concerned, quantity taken off is a very satisfactory condition to control. Flow controllers may be located on the draw-offs, and once these have been set to give the quality required, no further attention is needed, provided the feed rate and temperature do not change and adequate top reflux is provided. The internal reflux below each side stream draw-off will adjust itself automatically. The alternative is to adjust this internal reflux (or the draw-off, which is the same thing) to give a constant temperature at each draw-off plate, but in practice this method is not found to be so easy to operate, whatever its theoretical advantages may be. If the quality of the feed should change, the flow controllers will, of course, have to be re-set, but so in practice will the temperature regulators, though to a smaller degree.

To sum up, such a unit will have, as the principal instruments, a pipe-still outlet temperature controller, a tower-top temperature controller operating the reflux, flow controllers for the various kerosene and gas-oil side streams, and a level controller on the tower base. The same applies to a vacuum still making lube cuts, where it is generally found that the division between pressable and non-pressable cuts is very much a matter of percentage taken off.

The second case to consider is a pressure-still cracking residue to tar, gas oil, and pressure distillate. Control of coil outlet temperature to within 2 deg. fahr. and gas separator pressure to within 1 percent are the first essentials. The former should be possible with


If Rock Bits Could Talk . . .
(Type "OSQ-2")
"Well, here we are.. I'll handle the Gyp and Anhydrite"
(Type "OWS")
"I'll take the Dolomite and Lime!"
(Type "HR")
"But don't tackle the Chert..that's my job"

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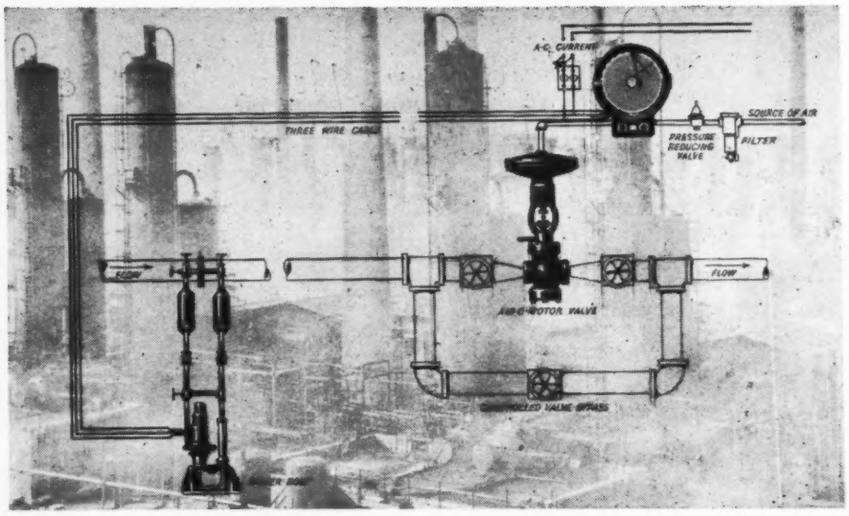


Fig. 4. Flow controller with electrically-operated distance recorder. (By permission of Messrs. Honeywell-Brown, Ltd.)

modern stabilized instruments and gas firing, and the second is certainly possible under steady operating conditions. The only remaining conditions the control of which is debatable are feed to the coil and gas oil draw-off from the column. It is the author's view that the flow to the cracking coil should invariably be controlled by an instrument, and any changes necessitated by levels building up or falling should be dealt with by the operator moving the control point of that instrument if the flow rate must be changed. If the charge pump is steam-driven, the most effective system is a flow controller acting on the steam supply; if electric drive is used, the flow controller must act on part of the oil stream itself.

With regard to the gas oil draw-off, it should be remembered that, owing to the large amount of excess heat fed to the evaporator and fractionating column of a cracking unit, there is usually a reflux point below the gas oil draw-off by which the quantity of gas oil (and also the quality of the recycle stock) may be controlled. Either a flow ratio controller, proportioning the reflux to the net gas oil make, or a draw-off point temperature controller might be considered, but in practice the latter is better. The reason for this is purely an operating one. Cracking operations sometimes get out of hand, and a not uncommon trouble is for top reflux to be lost, in which case the gas oil produced will momentarily decrease. If a ratio controller were used to fix the amount of intermediate reflux, this also would decrease, whereas, to get control of the unit again, an increase is required. A temperature controller would, in nearly all cases, help to give this.

A third case is the gasoline stabilizer, the proper function of which is to produce, as a bottom product, the maximum yield of gasoline of a given vapor pressure. The operating pressure being fixed, it is therefore essential to fix the temperature of the final product leaving the column base or the reboiler, as the case may be, for which purpose a temperature controller is naturally selected. In order to ensure the maximum yield of stable gasoline, the degree of fractionation must be controlled both in the rectifying and stripping sections. Usually, the most satisfactory way of doing this is to employ a feed-plate temperature controller regulating the steam to the preheater and a reflux ratio controller proportioning the reflux to the net overhead product, liquid or gas. To employ temperature controllers both top and bottom may be quite unsound, because it represents an attempt to divide a feed having, in most cases, a varying vapor pressure into two components of fixed vapor pressures. Only in one case in a thousand would this be consistent with maximum yield.

(ii) *Selection of Point of Control*

To one who is fully acquainted with the operation and duties of a plant, the selection of the point at which the measuring part of a controller should be attached is largely a matter of common sense, but too often the decision is left to someone without the necessary knowledge. The following observations may help to avoid mistakes in this important matter.

First of all it is necessary to decide what the instrument is really meant to control, and then to connect it to measure the quantity that really matters, *e.g.* the bulb of a stabilizer column base temperature controller should not be put in the reboiler vapor outlet, but in the final hot liquid product just before it leaves the column.

In the case of a crude oil pipe-still the important temperature is the flashing temperature of the crude as it enters the column, not that at the end of the pipe-still itself, therefore the controller should be placed close to the column just before the release valve, if any. Every operator has experienced the minor upset to a plant that is caused by a sudden shower of rain cooling the line (lagged or not) from the still to the tower. The instrument can help to avoid that if it is properly installed.

The bulbs of column-head temperature controllers require special care. They should be as close to the vapors rising from the top plate as is possible without risk of being splashed by liquid, but they must be kept well away from reflux. A safe place is in the vapor line, just where it leaves the column. Whatever may be desirable theoretically, the liquid and vapor on a plate or in a column base are never found to be at the same temperature, so that a temperature bulb must be wholly in one or the other.

The pressure tap for a pressure controller should be connected to a point where flow is steady or the vapor is quiescent, not close to the controller itself. Where distillation is being carried out under pressure and vapors pass from a column through partial condensers to a gas separator, it sometimes pays to take the pressure tap from the column itself instead of from the gas separator, because of surging in the condensers.

Where the temperature of a side stream draw-off has to be controlled, it is generally good policy to place the bulb in the vapors rising from the plate below the draw-off plate.

In all cases where temperature bulbs are inserted into columns they should enter at least 2 ft. or one-half of the column diameter, whichever is less.

When the manometer-type level controllers are used to control the level of hot liquids, care must be taken to install the vapor leg so that condensation of vapor cannot occur in it. Usually this means employing gas-oil seal pots.

In most cases, modern stabilized controllers operate most effectively where the whole of the fluid being controlled passes through the diaphragm valve. These valves should be placed on a partly open by-pass only if experience shows this to be necessary. Nevertheless, the designer should always provide a by-pass line for maintenance purposes, unless cost is prohibitive.

(iii) *Stabilization and Time Lag*

In many cases there is an appreciable time lag in refinery processes, in the

sense that from the moment when a controller attempts to correct an out-of-balance condition to the moment when the measuring instrument can record the correction effected, is a measurable length of time. The uncontrolled time lag in modern instruments themselves is negligible, and if they are installed in accordance with the observations made in the preceding section there will remain only the necessary process time lag itself to consider. The ill effects consequent upon this, however, would be enough to interfere seriously with the satisfactory working of most of the earlier types of instrument, and even today it makes automatic control much more difficult than it would be otherwise.

The relationship between process time lag and the instrument is extremely complex, but the important point to bear in mind is that when a condition change—say, a small change in pipe-still outlet temperature—occurs a controller can measure only the magnitude of the change itself, and not the magnitude of the force causing it.

From this it follows that the instrument cannot determine (nor could any human agency, except by experience) the exact amount of correction to apply; whence every control instrument must be designed basically to over-correct the condition change, if it is to control at all. Now, the longer the period of time between the controller coming into action, *i.e.* the moment when the over-correction is first applied and the moment when the measuring element can record this and cause the controller to commence under-correcting, the greater will be the amplitude of the swing set up. For example, in the case of the pipe-still many seconds may elapse before the effect of an excess of burner gas is felt at the oil outlet, *i.e.* before the controller can start to close the burner gas valve. Theoretically, there is no reason why the resultant temperature swing should ever die down and, in practice, with instruments of a few years ago, it often did not.

In addition to the above, there is another factor, connected with the instrument itself, which, though fundamentally distinct, makes the above situation worse. Almost all instruments in their simplest form possess a definite relationship between the condition change recorded on the measuring element and the degree of opening of the control valve, *e.g.* if a controller is set to hold 600 deg. fahr. on a pipe-still outlet when 50,000 cu. ft. per hour of burner gas is passed, then, supposing more burner gas is required, the temperature will have to fall in order that the control valve may open. Hence, if there is a fluctuating rate of feed to the pipe-still, the controller cannot help but allow a fluctuating outlet temperature. This is why, a few years ago, operators were obliged to "re-set" their instruments every time there was an appreciable change in throughput. Here again process time lag will cause a continual swing in the "controlled" temperature.

Both these troubles have been largely eliminated in modern instruments by the incorporation of stabilizing and automatic re-set devices. The principle of these is briefly as follows: instead of waiting for the controlled condition to re-correct the position of the control valve, an attempt is made to do this by using the change in air pressure on the diaphragm of the control valve as soon as it occurs and also the change in fluid flow (or pressure) immediately controlled by the diaphragm valve. The instruments shown in Figs. 2 to 5 incorporate this feature, and in Fig. 5 it will be clearly seen that a connection is taken from the burner gas line pressure back to the controlling part of the instrument.

The principle of one such re-set device is shown in Fig. 6. The measuring element, in this case a thermometer, controls the position of the flapper, but its relation to the seat can be varied by means of the air pressure on the control valve diaphragm so that the degree of opening of the control valve is not dependent solely on the temperature measured. The seat is linked to a diaphragm located in the middle of the bellows shown on the right. Following a change, the air pressure to the right-hand side of the diaphragm is equal to that on the left-hand side only after a period of time because of the air-flow restriction tube, shown as a coil. By this means the instrument is enabled to detect and use to some extent the rate of change of temperature as well as the actual change itself.

The effect of stabilizing and automatic re-set features in modern instruments has been almost revolutionary as far as their application to refinery work is concerned. These features have, for the first time, made automatic control really possible in the sense that instruments can, in many cases, do as much or more than an operator is able to do by forethought and experience, in the particular sphere in which controllers are applicable.

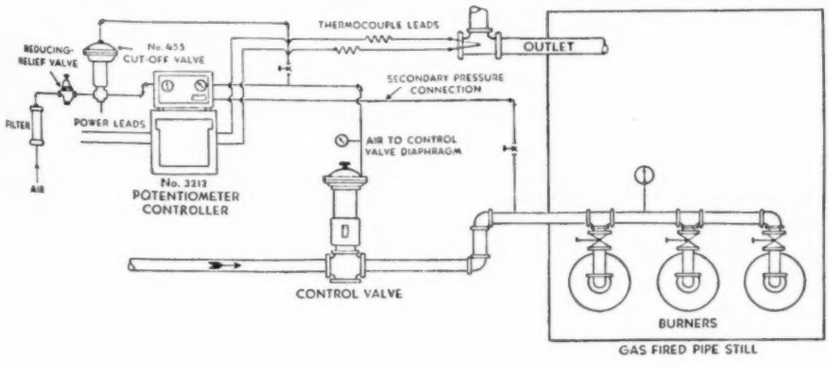
III. The Economic Aspects of Automatic Control

It was pointed out in the Introduction that automatic control of refinery processes can be advantageous in two ways. First it can control some conditions more efficiently than can the most experienced operator, and secondly its substitution for manual control may save operating labor and possibly overall running costs.

It is wise policy for a Refinery Management to insist upon the use of instruments of the first class, *i.e.* those that, in the opinion of the senior operating staff, will result in better operating efficiency. An example is the automatic control of pressure on gas plants and cracking-plant column. The installation of such instruments will result in an incidental saving of operating labor, but, together with meters necessary in any case, they imply the existence of an organization to effect their adjustment and repair. The question then comes, as to whether this organization shall be enlarged to take care of instruments of the second class, *i.e.* those installed purely to save operating labor.

A fairly close study of actual refinery operating labor costs in the U.S.A., Europe, and the Middle East leads the author to believe that, despite the large discrepancy in wage rates, there is not a very great difference in total wage bill per ton processed, because the cheaper labor is required in larger quantities. Real savings in labor costs are

Fig. 5. Pyrometer type air-operated furnace temperature controller. (By permission of The Crosby Valve and Engineering Company, Ltd.)



effected principally by employing large units and paying close attention to their layout and location with respect to other units. The most effective layout of a unit intended for hand control may often be improved from the mechanical aspect if automatic control is substituted, because the latter lends itself to distance operation. As examples of this, it is possible to locate pumps close to their individual duties, instead of grouping them in a single pump-house and employing long suction lines. Also furnace firing fronts may face away from the unit, with consequent increase in safety. Such points as these and the possible saving in capital cost accruing from them need to be taken into account, especially in large units.

The effect of automatic control on safety must always be considered, and it should not, at the present stage of development, be installed to such an extent as to reduce the labor available to deal with an emergency below a reasonable minimum. In this connection it must be borne in mind that automatic operation tends to reduce the familiarity of the plant attendants with the functioning of the unit. In an emergency, operators on a mechanically-controlled unit cannot be expected to act so quickly as if they had been controlling conditions themselves from day to day. The author has found first-class firemen on a cracking unit incapable of firing accurately by hand six months after automatic furnace temperature control had been installed. Against all this it must be conceded that centralized control in a single control house enables a really experienced operator to notice out-of-balance conditions more quickly, and renders him much more effective in an emergency unless the instruments themselves fail. A sound electrical supply and an auxiliary air system intelligently connected render this latter contingency very remote, as experience has shown.

Certain electrical control instruments may themselves be a fire risk, even though they belong to classes of instruments commonly employed in oil refineries. Special attention should be paid to this point. As far as possible all gauge and instrument lines to the control boards should be fitted with water or gas oil seals and, if proper attention is paid to this at the start, the risk of fire in a control-room can be reduced to negligible proportions.

If operating labor costs are to be saved by means of automatic controllers, centralization of the instruments and recorders is essential, which in turn means that to obtain the full benefit in savings, blow-down and similar valves should be capable of remote manual operation. The air-operated, hydraulic, or electrical gear for this purpose is an added capital expenditure, which must be taken into account.

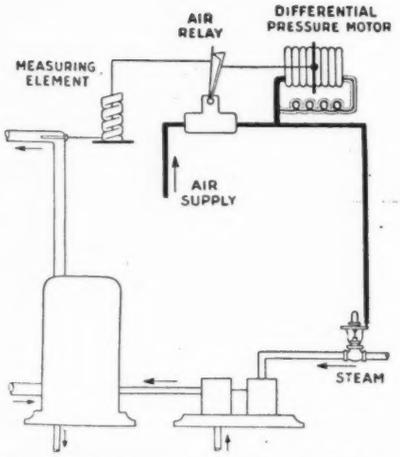


Fig. 6. Automatic re-set applied to temperature controller. (By permission of Messrs. Foxboro-Yoxall, Ltd.)

From what has been said, it will be seen that the factors affecting a decision for or against automatic control will vary largely with circumstances, such as unit size, availability of highly skilled instrument maintenance labor, and number of units in the refinery. The maintenance cost per instrument will be lower where a large number are employed. It is clearly not possible to lay down hard-and-fast rules, but the following example may serve to give an idea of what is to be expected from the installation of automatic control on a large crude distillation unit:

	£
Average cost of one instrument . . .	100
Installation, including piping and by-pass valves	100
Total capital outlay, per instrument . .	200
Allowing 5 percent interest on capital outlay and ten years life, the cost of the instrument per annum becomes .	30
Given a good service department in a large refinery the overall maintenance cost per annum would be approximately	5
Total cost per instrument per annum .	35
Assuming that 25 such instruments were used, the total annual cost would be .	875

The saving in operating labor, under favorable conditions, would be two to three men per shift or six to nine men per 24-hour day. At £150 p.a. per man this represents a saving of £900 to £1350 in labor costs to be offset against £875 for the controllers. In favor of the instruments, it may safely be said that operation would be smoother, and in the case of a really large unit, such as that in mind, an emergency could be handled more expeditiously. No allowance has been made for the installation of remote operated blow-down valves, but the capital cost of these should easily be saved by the simplified and improved unit layout rendered possible by the use of automatic control. For those who are contemplating the purchase of an automatically controlled unit for the first time, and who may therefore be a little dubious as to what is to be expected, it may be mentioned that many instruments can be purchased to include hand as well as automatic distance operation. These enable the unit to be run manually from the control-room, even though the more complicated parts of the automatic gear are out of action. It is the author's experience that, in any case, operators frequently prefer to use this manual distance control when bringing a unit on stream.

There remains the question of instrument maintenance costs. The first essential here is to staff the repair shop only with thoroughly qualified men, who must understand the refinery process as well as their own job. Frequent changing of staff should be avoided. It is often found that after working for some years around the refinery, the more ambitious among them make first-class operators by virtue of the process knowledge that they have gained on instrument adjustment work.

In some refineries the operators themselves are encouraged to learn sufficient about the control gear to enable them to effect minor repairs on site, whereas in others this practice is discouraged. In a small refinery there may be some economy in allowing operators to work on instruments, and also this work serves to relieve the monotony of keeping watch on an automatically controlled unit. However, in a large works, employing many operators, this course is hardly practicable, because with the increasing complication of instruments it is bound to lead to damage being done by ignorance, which ignorance cannot always be tracked down and eradicated. In a 200,000-bbl. refinery with which the author has been closely associated, about twenty-five instrument men are employed, a shift system is run and a member of the instrument repair staff is always present when a large unit is being brought on stream. In practice, with an experienced man, this strengthens the operating staff just at the time when it has to be strengthened, and it is a service greatly appreciated by the plant operators themselves.

The total instrument staff required in a refinery will depend to some extent on the part of the world in which it is situated, because in highly industrialized countries, particularly the U. S.A., instrument manufacturers can be depended upon to carry out a good deal of the major repair work that becomes necessary from time to time.

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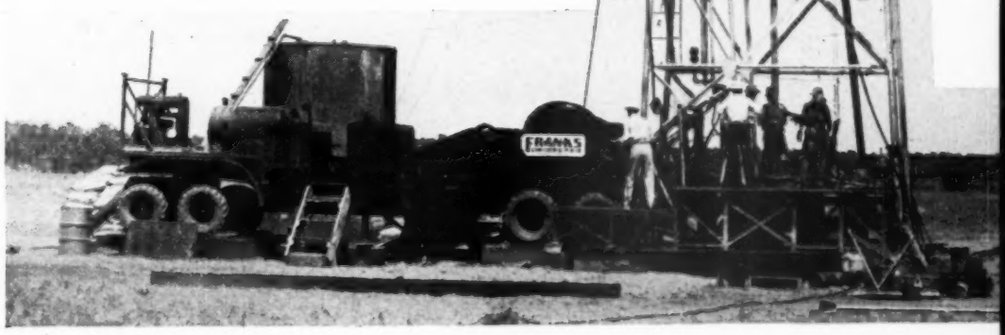
(At Right) View of Franks Model 5000 on Texas location.



(Below) Over the road position of this 100% portable unit.

Production and Reserves of Russia Are Being Increased Rapidly

The oil industry, recovering after a period of stagnation, must bear the burden of the industrial expansion

By RALPH H. KING

ALTHOUGH the oil fields of Russia had produced more than 2,630,000 bbl. of oil prior to 1871 and produced more than 50 percent of the world supply in 1901, undoubtedly exploration and development have lagged far behind the rest of the world. At present more than 75 percent of the oil produced in Russia is obtained from the old Baku district on the western shore of the Caspian Sea north of the Caucasus Mountains. Other producing areas are scattered from the north shore of the Black Sea to Sakhalin Island.

Baku District

The region that has always produced much the largest part of the oil produced in Russia is the district around the city of Baku, including the Apsheron Peninsula, part of the mainland, and the adjacent islands. The principal structural trends include the chain of domes on which are situated the Binagadi, Balakhani, Sabunchi, and Ramani fields. This anticline divides, one branch extending eastward and one turning southward. On this latter branch are situated the Surakhany, Kara-Chukhur, and Zykh fields. An offshoot on this branch extends southeastward toward Cape Goisan.

Other fields in the vicinity are the old Bibi-Eibat field, part of which underlies reclaimed land in Bibi Eibat Bay, Pirsagat, Artem Island (Mardakiani), Alyat-Saliani, Kala, Lok-Batan, Puta, Sulu-Tepe, Kergez, Kizil-Tepe, and Koushkhan.

In 1937 production from the fields of this district was:

Field	*Bbl. per day*	*Percent*
Balakhani-Sabunchi-Ramani	100,000	22.22
Bibi-Eibat	87,000	19.33
Kala	75,000	16.67
Surakhany	70,000	15.56
Lok-Batan and Puta	45,000	10.00
Kara-Chukhur and Zykh	44,000	9.78
Artem Island	15,000	3.33
Binagadi and Sulu-Tepe	8,500	1.89
Kergez	4,000	0.89
Alyat	1,500	0.33
	450,000	100.00

Many old wells have been deepened and many exploratory wells have been drilled in the last few years, thereby proving the productivity of additional sands in the old fields, extending the limits of the old fields, and discovering new productive areas.

The Balakhani-Sabunchi-Ramani area has produced oil since 1892 but in 1937 the field was extended a mile eastward. The Bibi-Eibat field, which is still older, was also unexpectedly extended in 1937 by large wells beyond the previous northeastern limits of the field.

Lok-Batan field was discovered in 1932; in 1933 it produced 646,300 metric tons of oil (4,815,000 bbl.). The oil is obtained from the "productive layer," the total thickness of which exceeds 1500 meters (4900 ft.), of which approximately 20 percent is oil sand.

Kala field was discovered in 1932 also and it produced 1,100,000 metric tons (8,196,000 bbl.) of oil in 1933. The producing formation is the same as that of the Lok-Batan field, and has the same characteristics.

In the Puta district southwest of Bibi-Eibat the Kizil-Tepe field was discovered in the early part of 1936. The discovery well produced 3500 bbl. of 36-deg. gravity oil per day at a total depth of 2200 feet.

In the same area the Koushkhan field was discovered a month later, the discovery well producing 2200 bbl. of oil per day from a depth of 5000 feet.

The Zykh field at the south end of the axis through the Balakhani-Sabunchi-Ramani, Surakhany, and Kara-Chukhur fields was dicovered in 1935. Several wells were drilled before oil was found at a depth of 5700 feet. The first producing well flowed at the rate of 7000 bbl. per day.

In February, 1936, the Pirsagat field was proved to be a major field. A well was completed producing 3000 bbl. of 34-deg. gravity oil per day at a depth of 4120 feet. More important than the quantity of oil produced, however, is the fact that the field is 50 miles southwest of the city of Baku and its discovery indicates the possibility of obtaining oil from a large territory not yet developed. The wells must be drilled through heaving shales, but there seems to be no great difficulty in doing so.

The deepest producing wells in Russia are those at the south end of the Surakhany field. They are approximately 8600 ft. deep and produced initially about 2000 to 3000 bbl. of oil per day through a ¾-in. choke.

Grozny District

Northwest of the Baku district but also on the western shore of the Caspian Sea is the area of second importance. It lies in the foothills of the Caucasus Mountains, which consist of three series of ridges. The southern ridge is nearer the mountains and is naturally the higher and more prominent. The northern ridge, so-called, is actually the central one. The most northerly fold is not reflected at the surface and is thus far known as the "Edessi Anomaly," being known from geophysical prospecting.

The southern foothills are known as the Sunjenski Range; the northern as the Terski Range. On the southern or Sujenski Range are the Old and New Gronzy fields and the semi-proven Shali and Benoi areas. On the northern or Terski Range are the Malgobek and Voznesenski fields and the Gorski Mountain, Taimaz-Kala, Mujim-Birk, and Gudermes prospects.

The new discoveries in Dagestan have been left undeveloped, but produced about 4000 bbl. per day in 1937.

Production was first obtained in the Grozny field in 1899. Both Old and New Grozny definitely have passed their peak of production and are declining. Most of the wells produce by gas-lift or pumping.

In 1933 the Malgobek field was discovered, the first three wells drilled having a combined potential production of 4000 bbl. per day. Four sands produce oil in this field. The daily production from the field was 22,400 bbl. at the end of 1935 and this rate was maintained through 1937, although the operators had hoped to increase the rate appreciably.

East of the older fields is the Dagestan area, in which the Izberbash and Achi-Su fields were recently discovered. The Izberbash field is a large structure on the shore and partly under the Caspian Sea. It lies close to the trunk pipe

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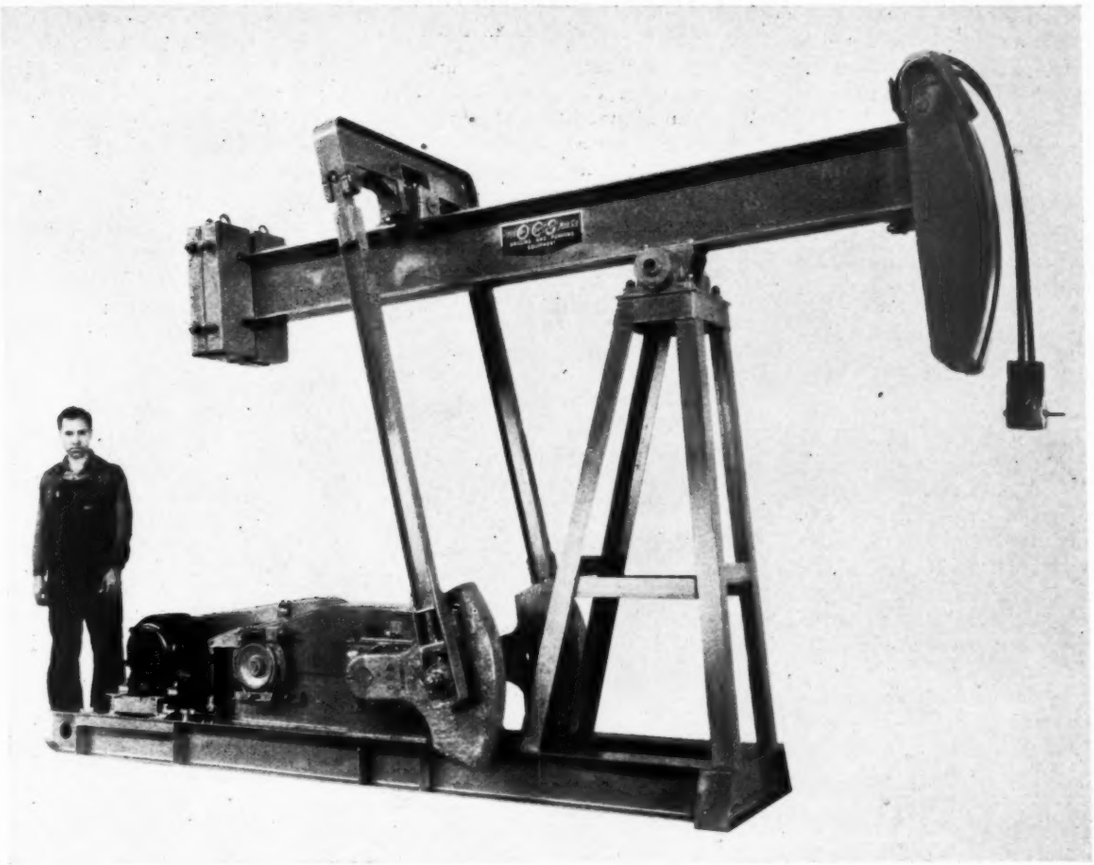

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(Double Reduction)

With Timken Roller Bearings and Diamond Roller Chain

FEATURES:

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- Stroke 24", 34"
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- For High or Slow Speeds
- For Electric Motor or Multi-Cylinder Engines
- Same Lubrication the Year Round

This 5-h.p. double reduction pumping unit is a miniature of all O.C.S. Polly type pumping units. It is identical in design, with all parts machined with the same accuracy and the same quality as the larger sizes up to 100 h.p. The one difference in principle of this unit is that it is provided with both a centrifugal and beam balance. This combination balance for a small size unit provides the unit with both the advantage of the centrifugal balance and the advantage of the beam balance. This machine makes the unit pumping of oil wells competitive with powers. It also gives the added advantage of individual well operation, which, production men agree, produces greatest recovery. Pumping wells at the speed and strokes that produce the most oil gives this machine a great advantage over central pumping plants.

The efficiency of roller bearings and roller chain provides this unit with the highest efficiency of any unit of this type and assures low power cost, particularly when electric power is purchased.

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line to the Grozny refineries. The discovery well produced 3000 bbl. per day from a depth of 5000 feet.

The Achi-Su field was discovered in 1936 also. The initial production of the first wells ranged from 70 to 200 bbl., but the depth of the wells is only 2400 feet.

Maikop-Kuban Area

The Maikop-Kuban district lies east of the Black Sea in the northwestern part of the Caucasus area. The area has been developed rapidly in the last few years and in 1937 produced 4.5 percent of the oil produced in Russia, even though the operators are handicapped by lack of roads, water supply, and other essential facilities.

The fields have been developed along the Kalujski-Apsheronski trend and include Asphalt Mountain and Kutaiski in the Maikop area and Adagum and Keslerovo in the Kuban area. The recently discovered Kura-Tzetze and Shirokaia Balka fields appear to be outstanding prospects but development has been insufficient to warrant any attempt at valuation.

The entire area is a rolling prairie lying close to the export ports on the Black Sea, hence the larger part of the oil exported from Russia should logically be drawn from these fields. The gravity of the oil is about 30 deg. A.P.I.

Emba District

The Emba district is a salt dome basin lying northeast of the northern end of the Caspian Sea. Approximately 300 salt domes have been discovered in the district, but the area is not comparable to the Texas-Louisiana Gulf Coast. Development has been greatly retarded by the inaccessability of the area, and the extensive faulting of the structures has reduced the percentage of successful completions far below the average for the rest of the country.

The production from the fields of this district is transported to Orsk by pipe line and is there refined. The quality of the oil is comparable to the best grades produced in other countries. The viscosity index of the lubricating oil obtained is 103 and the straight-run gasoline is 76.5 octane number.

The district has been producing oil since 1911 but in only a few years has it produced more than it did in 1914. The 1937 production was 1.36 percent of the production of the entire country.

The fields of this area include Iskin, South Iskin, Kos-Chagil, Shubar-Kuduk, Jakshilai, and Baichunas, all developed in the last few years. Initial production of the discovery wells in the South Iskin and Kos-Chagil fields was approximately 2500 bbl. per day, but it is doubtful that the potential production will exceed 10,000 bbl. per day.

Ural-Volga Permian Basin

New discoveries in 1937 appear to indicate that the entire area between the Ural Mountains on the east, Volga River on the west, the Emba basin on the south, and the province of Perm on the north is one province.

The Perm field has been producing since 1928 and in 1932 the Ishimbaevo field was discovered. It underlies an area of 900 hectares (2200 acres) and the first wells produced initially at the rate of 2500 bbl. per day. Ukhta and Chusov-Gorodki are in the same province and were also discovered in 1932.

The Ishimbaevo field has been developed rapidly because of its strategic position on the main routes of travel between the eastern and western parts of Russia and its situation in the interior where it is less exposed to attack in the event of war. By 1936 about 70 wells had been completed, of which only 26 were producing by natural flow, the others being shut-in because of lack of pumping equipment. The potential production had been increased to 30,000 bbl. per day. In 1937 about 170 wells had been completed but the production had declined to 20,000 bbl. per day, of which only 15 percent was obtained from flowing wells. It is apparent that under present methods of production the flowing life of the wells is brief, probably owing to the character of the reservoir rock.

The most recently discovered fields in the district include Krasnokamsk, at the north end near the disappointing Chusov Gorodki area, which has a potential production of approximately 10,000 bbl. per day. Near Volga River in the Samarski Luki hills the Syzrian field was opened, twelve wells producing about 500 bbl. per day; in Yablonovo field the discovery well flowed at the rate of 1500 bbl. per day; promising showings were found in test wells at Troekurov, and at Zolny.

In the basin between the fields in the Samarski Luki hills and the Ishimbaevo field on the west flank of the Ural Mountains oil was found in wildcat wells at Buguruslan and Tuimaza, indicating that the entire basin may yet be productive. This area seems to be analogous to the Permian Basin of West Texas and New Mexico, both in structure and paleogeography, and seems likely to develop into a comparable oil producing area.

Fields in Asia

In the Turkmenneft district on the eastern shore of the Caspian Sea oil has been produced since 1873 but only in the last three years has production reached the pre-war rate. The structure seems to be analogous to that of the western shore, where the very productive Baku fields are situated, and the producing formation appears to be equally prolific.

The Neftedag field was discovered in 1933 and proved to be a very prolific field, accounting for most of the gain in annual production of the district. The total production of the district in 1937 was only 3,470,000 bbl., however.

The Sredazneft area includes Uzbek and Tadjik but has never been a prolific producing area. Its largest production was 1,387,000 bbl., yielded in 1937. This is only 0.65 percent of the total for that year.

Other prospective oil-producing areas in Asia include a small district on Amur River near the boundary of Manchuria, Lake Bakail in Siberia (at present conceded to offer little promise), an area at the mouth of Lena River on the Tamir Peninsula, which projects into the Arctic Ocean, an area on the Minusinsk Steppes, and a part of the Kamchatka Peninsula on the Pacific Coast. Thus far, however, the proved reserves are unimportant.

Sakhalin Island

In the Pacific Ocean south of Kamchatka Peninsula is Sakhalin Island. The southern part belongs to Japan and the northern part to Russia. Fields in the Russian part of the island have been producing oil since 1928. The production has been gradually increased until in 1937 the daily production was approximately 9000 barrels. The military importance of this area greatly exceeds its economic value, because of its strategic position.

Ukraina

In 1937 a test well at Romni in Ukraina produced about 5 or 10 bbl. of oil per day. The significant feature, however, is the fact that the well proved the existence of a salt dome and seemingly indicated the existence of a major salt dome basin, perhaps comparable to the Emba district.

Industry Unitized

Engineers in the fields of Russia are theoretically in an enviable position, as there are no problems of law and equity to hinder their work. In theory they are free to develop the fields along scientific lines without regard to property lines or royalty interests. Technical perfection should be attainable without interference by courts or civil authorities. Not only the fields but the entire industry is unitized.

A Geophysicist in the Netherlands Archipelago

An intimate narrative that conveys to the reader a vivid description of the life of the geophysicist on field work in the Tropics

By J. L. DAVIDSON, Geophysicist

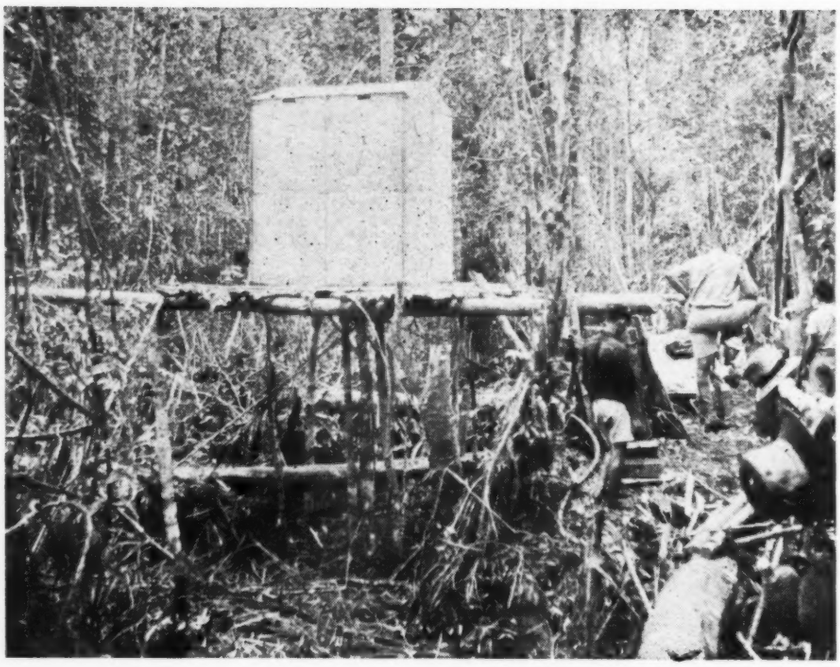
A PERSON'S first impression of Palembang, Sumatra, is one of not too wholesome nature. Usually the steamer arrives in Palembang from Singapore in the night, affording the newcomer only occasional glimpses of flickering lights from huts in native villages along the banks of Moesi River. The damp air hangs close to the surface, as in an old cellar. The musty air is hard to breathe and clothes become sticky. The N.K.P.M. (Standard of New Jersey and Socony Vacuum) refinery is seen only after passing a sharp bend in the river, and it affords some comfort by its elaborate display of electric lights. Across a small tributary stream is the B.P.M. (Shell) refinery. Farther upstream the newcomer will see pale flickering lights of the Palembang waterfront.

On docking in Palembang, there is usually much noise among the Malay natives and the Dutch ship officers, greeting their friends. No one is allowed to leave the ship until about eight o'clock in the morning, for it is only then that the customs house and immigration offices are opened. To the newcomer, on his first trip to the East Indies, this delay is annoying because of his feeling of the need of haste to explore this vast and interesting country, about which so little is known, but after a few months in this strange land, he can understand the uselessness of haste. If he will notice carefully on leaving the ship on his first entry, he will receive a very good lesson on the stubborn will of these people. It is plainly evident as the Dutch officers shout to hurry the coolies, who merely maintain the same slow pace that has been their habit for hundreds of years.

On my first trip I was hustled and bumped by the friendly Chinese and Malays. It seemed that we were all trying to get through at the same time. Had it not been for one of the company's interpreters, sent down to help me with my baggage and passport, I suppose I should have sadly brought up the rear. After much gesticulating to one of the customs officers, who was watching me out of the corner of his eye, we pushed through the mob from Singapore in about two hours to make a fairly fast trip through the customs house. The customs officials were particularly anxious to know if I had any guns. After satisfying them that I did not have, we were allowed to pass, and went into the small asphalt street that led to the refinery in one direction and to Palembang in the other. I had a good chance to see some of the natives and their homes; the native quarters were waterlogged from heavy rains, and the stench and musky odor of rotten vegetation did not impress me favorably. The natives were most interested in begging me to use one of the many worn-out cars that were used for taxis. By this time, the half-caste interpreter said that we were loaded and ready to go first to the company's staff-house. Passing from the docks we entered the residential section, where I was amazed to see numerous beautiful houses and large gardens full of tropical flowers. The sight of them was a real treat because I had begun to think that this was a rather dirty place to have to call headquarters.

When we arrived at the staff-house I was ushered by servants to a rather large high-ceilinged room, which had a connecting bath of Dutch type. There was a shower and a large concrete tub full of water. If one didn't care for the shower, he could bathe by standing on the side of the tub and pouring water from large gourd-like tumblers over his body. The usual temperature of the water in the shaded concrete container is about 70 deg., so it gave a great pickup after the hot day outside. I sat on the bed and discovered that it was about as hard as a ship's deck. It had a kopock mattress spread on boards. There were no innersprings or any other kind to be had. I saw a long pillow lying in the middle of the bed, and later learned that this

Transporting equipment by boat



A platform station site, three meters aboveground.

is called the "Dutch Wife." Its function was to prevent the heat from chaffing the inside of the sleeper's legs. One good thing about the Dutch-designed beds is that they have a large and high net bar over them to keep out the insects. I heard a rather strange chucking sound, and looking upward I saw several bloat-eyed lizards crawling around on the ceiling. Later I learned that they are called "cheechugs." They are harmless and useful, for they eat the insects, but at times they cause excitement by falling on someone when he least expects it. Later in the day I spent some time watching these fellows catch the numerous moths and other bugs that came their way.

After I had finished breakfast, the half-caste interpreter returned and asked me to go with him to the office of the refinery. Our ride to the refinery is an unforgettable memory. It seems that when they are in a car they try to make up for their lack of speed on foot. The road was narrow and had many curves. The driver went as fast around the sharp curves as on the straightaway. Later a driver explained why they drove as fast around curves as on the straight-away. He said that when the company made the car they put four wheels on it and if it was necessary to have something on the car to keep it from skidding they would have included it. When I asked him why it was that some of them did turn over, he merely said that was because the driver did not have his license or else it was caused by a devil. I let it go at that!

We left the car on the river bank and took the small tug-like ferry across the river. On arriving at the office, the half-caste seemed glad to get rid of me. When I was shown into the chief's office, I was welcomed in the usual manner but so many questions were asked about how things were in the States that it was about a week before I could ask any questions myself. One of the engineers from the oil field in the jungle came into the staff-house screaming like a banshee for a place to sleep. I was surprised to learn that he was an American. I invited him to share my room, which had a spare bed, and was repaid by his telling me strange and weird tales, far into the night, of how to act and how to treat the natives. It seemed that one is expected to make a big fuss all the time, so that the natives won't think that he is satisfied and quit working. I found out later that this was true only in some parts. My newly-made American friend had been in the islands for several years and took delight in explaining to the novice the fine and delicate ways of the natives.

The assignments for geophysical and geological explorations are of six months' duration. The prospector then returns to headquarters to give a complete, detailed report of his work. He also has a chance to repair his equipment, which is considerably damaged from the rough use in the jungle. The companies have found it advisable to give the prospector a two-week vacation every six months, as he deserves a rest from the routine work in the jungle. The steady grind in the darkness of a heavy jungle induces a morbid feeling.

On leaving Palembang for my work, I was told to return about once a month for supplies and money, and that I would work on a six months' assignment. My first assignment was only about 100 miles from Palembang, in the lower part of Sumatra. We traveled by car about half the distance. Then we had to use one of the company's motorboats that had been left at the village. We got an early start the next morning and traveled all that day in the boat, finally stopping at a small village where the river was too narrow and dangerous for the speedboat. The next morning we took a small native dugout and six men to paddle for us. I was surprised at the speed they could make and their ability to avoid the strong current. The stream was out of banks due to heavy seasonal rains. We were going into the very heart of the south Sumatra jungle and I could see many different kinds of monkeys; they chattered incessantly, making a lot of noise. We saw some deer and wild pig. Many crocodiles were noticed in the stream. I was amazed to see so many wild flowers. The trees were full of orchids. We did not reach the company camp that day, but spent the night trying to sleep in the dugout. The natives had a small iron pot in which they boiled some rice and fried some dried fish. The odor from that almost drove me into the water, but the beam from the flashlight illuminated the red eyes of the crocodiles all up and down the stream. My half-caste assistant and I ate some canned food. We were all in cramped quarters. While we lay on our thatch carpet I tried to get a glimpse of the stars through the heavy jungle above and all about us, but only when the evening breeze rocked the trees could I catch sight of a star. I gave up this game to listen to the many animals and insects that seemed to make the jungle alive by their steady noise. I realized then the jealous feeling that the jungle held for the intruder, and that no quarter was given on this stage set by nature. A cold chill ran down my spine. I knew that I was boss of the men on our small boat and would be in charge of the party that we were to join, but the sudden helpless feeling of being at the mercy of the jungle and so far from the people that I knew left me no desire for gloating over my position of authority. I tried some conversation with the assistant. I wanted to know why we were tied up close to some grass instead of along the bank. He explained that we were in

less danger from the animals in the grass and also from falling trees. This was all very encouraging! I began to grow tired and the assistant had the natives place a palm thatch covering over us to keep off the night rain. I soon fell asleep, only to spend a restless night trying to be comfortable on the boards that offered us a bed. Every time I awakened, which was often, the boatmen were still awake, smoking some kind of foul-smelling tobacco. At the first show of day we prepared to move upstream. The early morning brings a heavy dew and fog that make a person cold. I reached for my blanket and sat huddled as our boatmen carried us deeper into the jungle. About two o'clock in the afternoon the boatmen began to swing harder on the paddles. I asked the assistant the reason for the speed. After talking to the head boatman, he said we were nearing the camp. We were soon within hearing distance and, at sight of the camp, there was the usual shouting between the natives. We were greeted by the chief whom I was to relieve, more assistants, and many coolies. I felt that I was entering an army camp. I had known the party chief in the States so we had something in common. He was to leave this party in order to lead another in Sumatra. I was hungry and an excellent meal was soon prepared. I was surprised to find the food here in the jungle better than that served in Palembang. Of course, the fresh deer and pig meat was a treat. My friend informed me that the company would allow one any kind of food one wanted and as much as one wanted. We had much to discuss and retired late, sleeping beneath a fly tent on a raised platform. Our floor was made of small trees tied together. It was awkward at first to walk on them but a fellow soon learns to be at home. There are so many deadly small snakes that all precautions must be used. Also a tropical rain may cover the ground to a depth of a few feet on short notice. The pole flooring also gave a little change from the muddy trails, of which I was to learn the next day.

It is necessary to tell the laborers each day that there is work to do, that they are to do the same job in the same way that they did it the day before. It is necessary to repeat orders every day. The laborers never have been allowed to think for themselves. Of course, those of such professions as cook or motor operator know that they are allowed to use their own judgment in their trade. Our foreman knew what he should do, but came to the tent each morning or night for confirmation of the order.

The camp awoke early, and I saw, from what the other party chief was doing, that I would have to spend most of my time at work in the early morning. Orders had to be given to all. We soon finished the camp work and started along the trail to see how the work was done. I was amazed to see the efficient way in which the work was performed. The men had very little equipment, yet they were turning out more and better work than in the States. I was surprised at the strength of the coolies and the orderly way in which they did their work. I was expecting to see sulky savages but these fellows were going about their work in a way that made me think they might be enjoying it. I immediately liked them and enjoyed working with them for the full duration of my stay in the islands. As we walked down the trail, the other party chief explained to me that he was just moving back into the jungle, away from the stream, and that I was lucky not to have to do very much walking on my first trip, as in only a few days more the camp would be 30 miles inland. The camp was moved in ten-mile intervals. The work here required lines 30 miles long. We would then turn 90 degrees for five miles then back another 90 degrees for a parallel line. On finishing we would have several parallel lines all tied together. I could see that the work was being planned and performed with skill, for supplies and future trails had to be kept far in advance, and yet not too far lest the trail grow back and become impassable from falling trees. I was told that the coolies were divided like an army. There were certain duties for different gangs. The transport coolies were working like ants, running at a slow trot that they called "pickling."

I soon learned to walk with the best of them, and never thought very much of a 20- or 30-mile walk in one day. We averaged about ten miles per day. We had to keep one month's supplies with us all the time for we never knew just when the high water would isolate us. The natives ate rice, dried fish, red peppers, and green dried beans. We gave them tea and brown sugar. Coconut oil was used for cooking. All food supplies for the assistants and the party chief were canned. They were heavy and hard to transport but a white man cannot adapt himself to the native food.

Our crew consisted of an average of 150 coolies. We used 14 as the day crew and 14 as the night crew; our engineer, a native educated by the Dutch, used 16 coolies to help survey the work; we used 20 to 50 coolies in preparing the station sites. On ground we would grade the stations on a 3-meter radius, whereas in swamps and water we would set them on platforms made from poles or the stump of a large tree cut about three meters from the ground. The station makers would use rattan, a vine found in the jungle, to tie the platform together. As the only added expense in operating at night was one operator and 14 coolies,

A field camp

the company found it best to operate 24 hours per day.

Most of the rest of the coolies were used as transport men, whose duties were to move the camp and keep supplies in camp at all times.

Besides the coolies I had three Dutch assistants who were trained to observe the instruments. Only two helped to erect the stations, one being in reserve all the time to compute the results.

The photographic plates were developed beneath a cloth with which the observer would cover his head and the containers that held the developer. We found it necessary to harden the emulsion on the glass plates to prevent it running or becoming distorted.

A field map was kept up-to-date by the engineer, as at times it would serve to help to direct the work.

We worked on a 24-hour basis. We never stopped for anything. The heavy seasonal rains slowed us some, but we built pole bridges down the trail and carried on. Our race against time was to reduce the expense of the work. The average cost of stations was $40.00 per station. Our expenses in the field were about $5,000.00 per month. I was given cash for this sum, and, at first, worried about carrying such a large amount of money, but I soon learned that I was the only one that was worrying so I rested much better knowing that danger of theft was out of the question, especially when we were so far in the interior.

I soon became acquainted with the "potshot" (leech). These little bloodsuckers left many scars on my body from the infection caused by pulling them off before they were ready to fall. They were not painful while they were sucking, and generally the feel of warm blood running on the skin would inform me that I had been bitten. We used iodine to make them turn loose, which killed them instantly. I enjoyed the absence of the ticks with which I had had so much trouble in South America. The mosquitoes are there by the millions and many of them carry malaria. After fighting them for a time, I decided that the best thing was to let them get their fill and then we all could rest,

It was only after a couple of weeks with the other party chief that we went into Palembang, where the work was officially turned over to me. I returned to the camp alone. I learned that geophysical prospecting was introduced in the East Indies by the Royal Dutch Shell and that the Standard Vacuum and the Standard of California soon followed. The magnetometer was first used, and as a reconnaissance instrument, but was found to be reliable only in Borneo, because of the large magnetic corrections in Java and Sumatra. After checking the magnetometer by core drilling the companies discontinued the practice of using the magnetic instrument. The next instrument was the z-bar-type torsion balance. This instrument has proved very valuable in all the islands. It has been instrumental in locating prospects for future production. The islands are comparable to the Gulf Coast area. There are some places where the seismograph must be used because of severe cross-bedding that makes gravity work precarious. The gravity results must be carefully interpreted because of the sharp folding of the structures. At present the seismograph is doing much to reduce the expensive core drilling, to which is left only the final proof.

Core drilling indicated that the structures mapped by the magnetometer did not exist. After careful re-

Torsion balance in swamp platform site

checking the error was attributed to the presence of iron deposits, as it had been attributed to other metals and conditions in Sumatra and Java. I believe that the magnetic deposits that the volcanoes have thrown over the surface of the islands from time to time are largely to blame.

Naturally, because conditions in the islands are so unfavorable for exploration and drilling, all guess work in locating a well must be eliminated. Therefore, when the field geology and geophysical work have been completed, a core-drilling unit capable of drilling to depths of 3000 ft. is used. Core holes are correlated in minute detail. On completion of this work, the core drill will usually be used to make one or two deep tests to determine whether the sands are prolific. Even if promising sands are encountered, the prospect is left until such time as needed. This precise work is justified as the government requirements for obtaining concessions and permits to drill are very strict.

The cost of drilling the wildcat may be as much as $100,000.00 under normal conditions, because of the high cost of road construction and of transportation of heavy equipment by special boats and barges.

Java is highly civilized and has modern conveniences, paved roads, railroads, steamships, and airplanes, which can quickly and easily take one to any part of the island at minimum expense. This island, however, is regarded as being unfavorable for any large oil deposits as about 75 percent of the surface of the island is basement rock and is rough and mountainous. On the rest of the island, along the east coast, there are a few basins that include some small and shallow oil fields. Near Batavia, on the north end of the island, near the world-renowned volcano Krakato, is a swamp about 25 miles in diameter, where extensive geophysical work has been done by all the companies, but from the writer's knowledge there is nothing of value in this basin and this is about the only place where a large structure might have been found.

Sumatra is similar to Java in shape, and has along its west coast the same mountain range that parts Java in the middle, so the east half of the island is favorable for oil-bearing structures. Here the torrential rains have not eroded the Tertiary formation that includes the producing sands. The eastearn part of Sumatra is a long swamp, extending the full length of the island and extending into the interior as much as 150 miles. It is this area that is being explored extensively. Several large structures have been found on which large oil fields probably will be found in time to come. The writer was instrumental in finding some of these structures by using torsion balances. Our work was confined to the places where it was impossible to use a seismograph. In these areas the heavy jungle is growing on a sea of moving alluvium, in places as much as 500 ft. in depth and in a quicksand stage. The seismograph was useless because of the continuous vibrations. It was necessary to drive long pole pilings to support the torsion balances. We found that a large tree cut three meters from the ground formed an excellent base for the instruments. Around the tree trunk we would build a platform for the hut or instrument tent. This was risky work as only one man could carry the instrument to the platform, and if he had slipped, more than likely it would have been the end of a valuable instrument. The men were cautious at all times, however, and never

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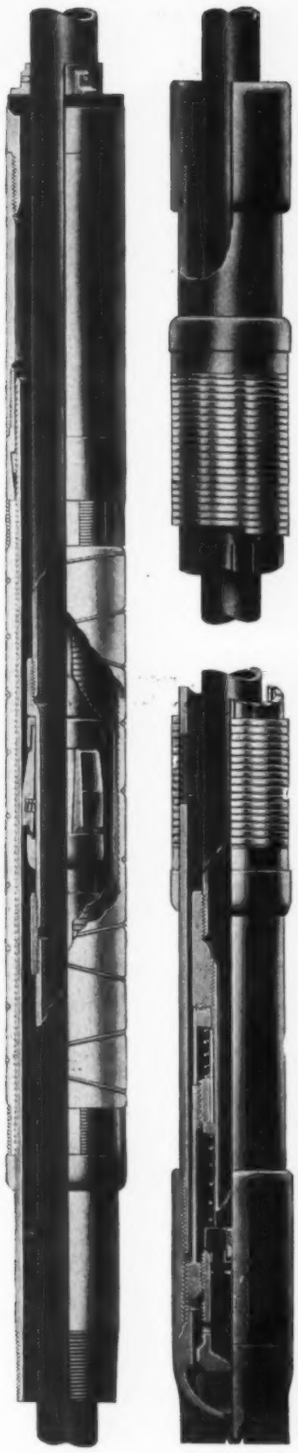

TEXAS IRON WORKS

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slipped. The Malayan coolies had to work a long time to earn promotion to carrying the instrument, which they considered an honor. Silt deposits would accumulate around the base of the trees. It was necessary to raise the instruments above this mass as it gave considerable attraction. The torsion balances were adjusted for sharp temperature changes, as rain storms caused temperature drops of 15 to 20 degrees. It was possible to use a tent comparable to a teepee for the instruments. This afforded an appreciable saving as the moving time was reduced considerably and the crew was reduced from 14 men to only five.

Sumatra is still in a rather primitive stage. Only the aboriginals know anything about large parts of the interior. To prevent bloodshed, the government tries to gain their confidence slowly without hostile maneuvers. Naturally, the prospector is sent to these places for first claim to any prospects. There are no roads. We carried our supplies up the streams.

The streams in Sumatra are deep and have steep mud banks. At times the swift streams whirl a boat into the banks but she can be reversed and the bow slipped from the mud. The bars at the mouth of the streams are shallow, so it is necessary to use boats having a draft of only a few feet to pass over the bar, but the river may be as much as 150 ft. deep, as is the Siak in central Sumatra. The swift current is caused by the high tides piled on the east coast. Some of the rivers on the east coast of Sumatra are dangerous to navigate, owing to the bore at the mouth of the stream. These bores constrict the tides in a wall several feet high and unless a person is well acquainted with the time of the tides, he may find himself trapped in a very short time. Numerous shipwrecks have been caused by this maelstrom of cross-currents.

The Malayan coolies are strong and take pride in carrying large loads great distances to prove their strength. I have often seen them carry loads of 80 lb. a distance of ten miles without stopping. The trail would be deep mud and water. I found that if I showed a very little respect for their customs they would try to do everything to please me. They do not like to be the center of a joke and cannot stand to lose face under any condition. We would try to make any problem that they thought important as important as they thought it was. We drove our trades only far enough that the company would not be treated unfairly, leaving the trader enough margin so that he could make a decent profit. The prospector must even be a good horse trader. The natives like to sit and argue for hours over a few pennies. Regardless of how much the prospector might value his time, it is imperative that he sit and drive the bargain for it is a challenge, and failing to meet it he will lose the respect of his men. The hours of our coolies were long, and they were paid only a few pennies; however, the company by which I was employed paid larger wages and gave better food than the average. We paid 40 cents per day and food. This amounted to about 30 cents per day, American money, and food. The average wage scale among the coolies in all the islands is 15 cents, Dutch money, per day; the equivalent in American money would be about 10 cents per day. Strange to say, after paying about half of this as taxes, they have enough to support their families after their own standards of living. The writer has also worked in Venezuela, in charge of torsion balance work, and can see no comparison between the people of the East Indies and those of the West Indies. The East Indians' character may be the result of the Mohammedan religion, as they live strictly by its teachings. It forbids the use of intoxicating drinks. The Mohammedan religion requires the native to bathe at sunrise and sunset. They are unusually clean. The morals of these people are much higher than the dime novels and movies rate them, and a fast way to die is to molest their women. They will go to work chanting some native song to which they will add words as they sing, and if the prospector will listen closely he will find his own name mixed in the song, maybe in praise, maybe criticism, or maybe warning. It is wise to listen, for the advice is sometimes worth taking. They don't try to sing their chants directly or indirectly to you. They will never try to suggest a different opinion that would probably save time and money for they have been taught by their Sultan rulers never to voice their opinion to their superiors but to do what they are told to do.

The gravity meter instrument used by our party was chosen because of its simplicity of operation and rigid construction. The automatic photography of the readings was also taken into consideration, as the photographs give a better record of the readings and indicate any tampering by the observer or misalignment of the instrument. We found this instrument nearly foolproof.

In recent years several gravity meters have been placed in service in the islands, and unless they were satisfactory, probably only one would have been sent. The gravity meter will be an excellent instrument with which to work the streams, but for use in the jungle it will be no more accurate or rapid as only about 3000 meters of trail can be cut in a single day, regardless of the number of men in the trail, because only one man can work in the head of the trail at a time.

Owing to a fungus growth that is strong enough to etch glass, it is necessary to take the instrument apart often and clean it well. The party chief should, therefore, be able to disassemble the instruments completely, clean them thoroughly, and reassemble them in a fairly short time, to prevent delaying the work. Even the clocks, motors, and recording apparatus must be taken apart. The high humidity of the jungle causes moisture to condense on the instrument; this condition at times becomes so acute that a gasoline lantern must be lighted in the instrument house to keep the instrument dry enough to permit observations.

The party chief is thrown completely on his own resources to handle any situation that may arise. He will even find use for medical training, surgery as well as first aid. He should be trained to judge men under all conditions.

The islands will hold a fascinating appeal for the prospector for any amount of time that he may spend there—the many thousands of square miles of unexplored territory, the natives and their "black magic" doctors, who perform miracles before his very eyes, the many strange experiences that he can keep only as memories. The prospector will leave part of himself in the islands, a part that will always be calling for him to return. The hardships of working in the jungle aren't imaginary. The work is lonesome and, at times, monotonous, particularly when the monsoon brings heavy and continuous rains. The days are short and the jungle takes on a morbid black aspect from the lack of sunlight. At times one is completely locked in the jungle by swift swollen streams that have cut all lines of communication. But even after experiencing all that, he will say that he had a good time and will find a yearning to return that is hard to control. There the "savages" have found a peace that we are still seeking. I am convinced that we are the uncivilized and savage; that they, at some time, have gone through the same evolutionary stage and are now content to remain in a plane best suited to the natural contentment of their minds. I know that they are a happy and fearless race of people.

General view in the old portion of the Moreni field, Bana district in the distance

By
K. C. SCLATER

Modern Development Practice in Roumania's Deep Fields

Drilling and production methods approach the most advanced standards of other areas

AT the close of 1937 Roumania had 43 producing oil and gas fields the total area of proved oil and gas lands in which was 40,290 acres.[1] The oldest field was discovered more than 77 years ago, since when Roumania has produced more than 800 million bbl. of oil. The present average monthly oil production is between four and five million barrels.

The productive formations are Pliocene, Miocene, and Oligocene in age. Most of the production is obtained from the Meotic, which is of Pliocene age. Besides being most prolific of oil this formation is quite widespread, being productive in most of the oilfields in Roumania.

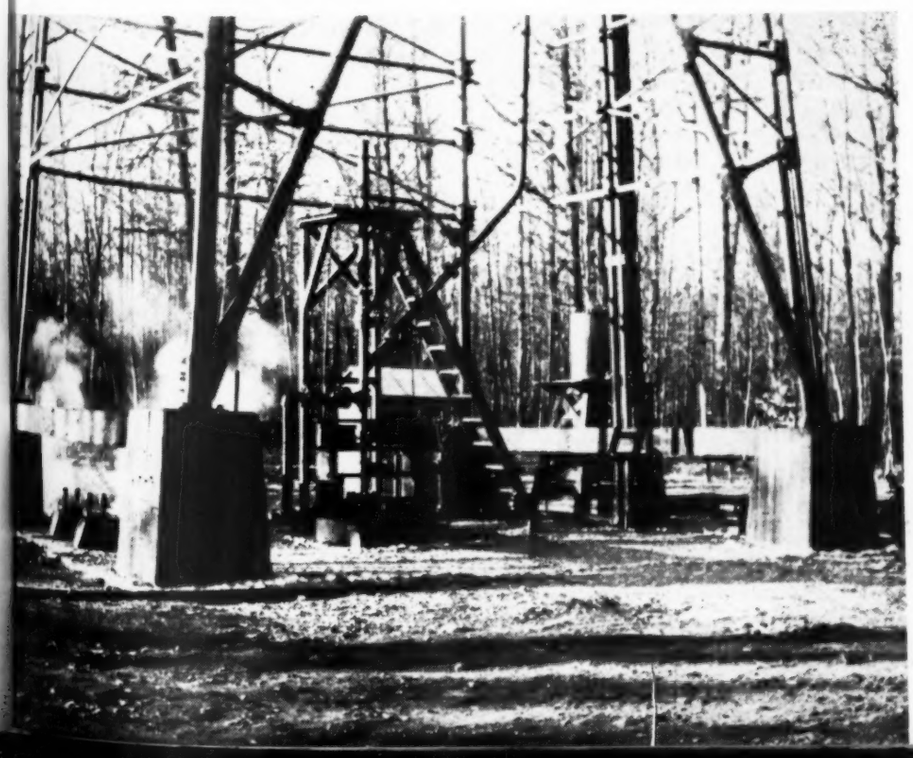
In the oldest fields (in Bacau and Transylvania) the wells range from 1000 to 2200 ft. in depth. Elsewhere in Roumania the wells range in depth from 1000 to 8400 feet. A prospect hole was drilled to a depth of 11,000 ft. in the Tintea field, Prahova. It is interesting to note that the Tintea field is in one of the oldest producing regions in Roumania.

In areal extent, the five largest oil fields at the end of 1937 were:[1]

West Gura Ocnitei	7550 proved acres
Bustenari . . .	5250 proved acres
Boldesti	4890 proved acres
Bucsani	3900 proved acres
Moreni	3700 proved acres

Modern drilling methods, mainly rotary, are now used in the newer and deeper fields. Drilling practices employed by the important and efficient companies operating in Roumania follow closely those of the United States. Blowout preventers, heavy mud pumps, control of drilling mud, and gun-perforation of blank pipe, are employed in standard modern drilling practice.

[1] "Oil and Gas in Roumania," p. 683, A.I.M.E., Petroleum Development and Technology, 1938.



Rallet apparatus for deparaffining tubing, and platform from which it is operated, Moreni field

Pumping unit on well in Moreni field

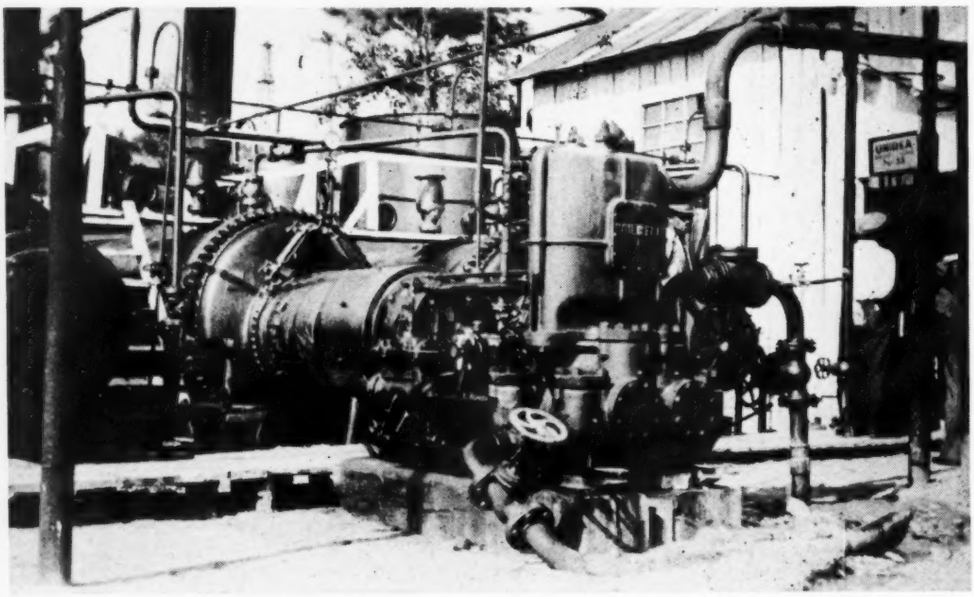
The rate of drilling compares favorably with the best practice in the United States. For example, on a 4000-ft. rotary well the drilling record shows:

April 27 to May 2, moving in and rigging up, five days; May 2 to 26, drilling and completing well, 25 days.

One company that has its own drilling tools reports that tearing down, moving, and rigging-up time averages less than 14 days per well.

Typical casing programs consist of 12-in. or 14-in. surface casing and 8-in oil string, or 10-in. surface pipe and 6⅝-in. oil string. There is a trend toward smaller casing strings because of the decrease in casing cost obtained and also because of other economies resulting from drilling a smaller-size hole. Most of the large companies have standardized on the drilling rig set-up and so have reduced rigging-up time.

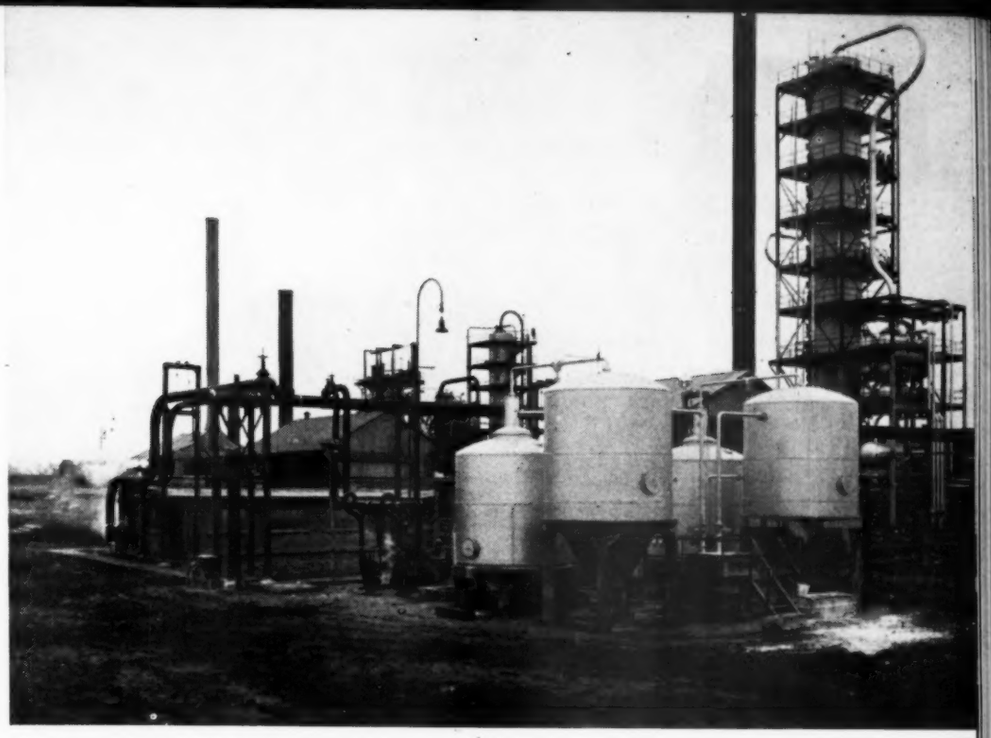
In seeking to reduce drilling costs in deep wells much effort has been put forth in furthering the faster and safer completion of wells. This has resulted



Modern open-type feedwater heater-pump unit serving an oilfield boiler plant, Tzintea, Roumania

in the adoption of equipment and practices that reduce the possibility of accidents and delays during the drilling and completion of wells. Close attention is paid to the selection of suitable equipment, drillers, and drilling crews. The importance of close control of drilling mud characteristics during drilling in keeping the hole in good condition at all times is recognized by companies operating in Roumania. Evidence of this is the practice of maintaining the drilling mud at the proper viscosity, the use of vibrating screens, adequate settling arrangements, and rapid circulation. In following this practice, operators in Roumania are fully cognizant of the benefits to be derived in the reduction of

Headers for wells to central collecting station at West Ghirdoveni, Moreni field, including clean oil, wet oil, and gauging headers



Water-treating equipment at Teleajen refinery, crude oil pipe still, bubble tower, and cracking coil in background

wear on mud pumps and pump valves, and the reduction of wear on drill pipe and bits.[2]

Economical steam generation is practiced at steam rotary rigs. Where necessary, boiler feed water is treated, and boilers are lagged and superheaters employed for efficiency and economy.

Modern equipment used on the derrick floor includes instruments by means of which the driller has under his constant observation and control every important phase of the drilling operation including: weight on the bit, table speed, mud pump pressure, torque on drill pipe, and the total load on the derrick.

The reported number of producing wells in Roumania at the end of 1937 was:

Flowing wells . . .	190
Pumping wells . . .	969
Gas-lift wells . . .	240
Miscellaneous wells* .	634
Total	2033

*Produced by methods other than those enumerated.

Other than difficulties of an economical nature no particularly acute difficulties are encountered in drilling and completing wells in Roumania.

[2] "Deep Well Drilling: Discussion by Roumanian Branch"—Journal of the Institute of Petroleum Technologists, June, 1937.

Modern production practice in the Roumanian fields follows closely practice in the United States. This is particularly so in the operation of deeper producing wells.

At one time sand troubles were quite prevalent in the Roumanian fields, but in recent years difficulties from this source have been greatly reduced by the use of perforated pipe, screen pipe, or liners in the completion of wells.

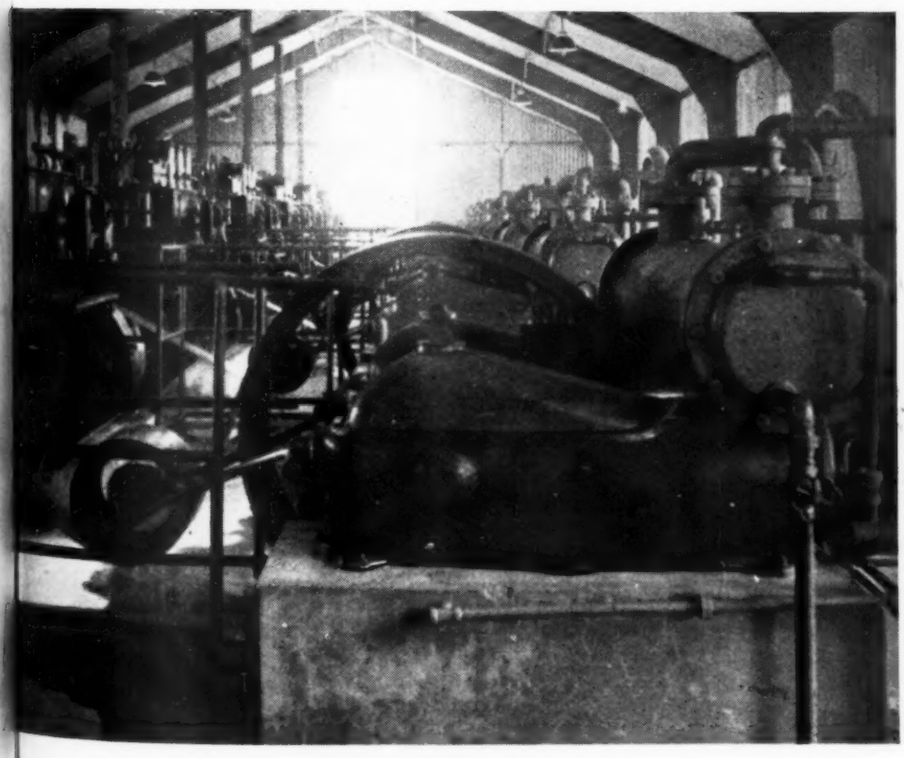
Many pumping troubles were aggravated by crooked holes, and these, together with fine sand, were the cause of extreme wear on rods and pumping equipment. Troubles of this type led to the use of the gas-lift, which was tried and found successful as an economical method of production in many wells so troubled. Today the gas-lift is in wide use as a production method in Roumania. In some fields, gas-lift is used in a large percentage of the producing wells.

Wax, or paraffin deposition, is a universal problem in producing wells, in well connections, in flow lines, and in tanks; and many systems are in use for combatting this difficulty. As is common in oilfields where paraffin deposition is a problem, the waxy deposit usually forms on the inside walls of the tubing at the surface of the well and may extend to a depth of 800 to 1000 feet. The deposition is caused by the cooling effect of the expanding gas on the oil as it nears the surface.

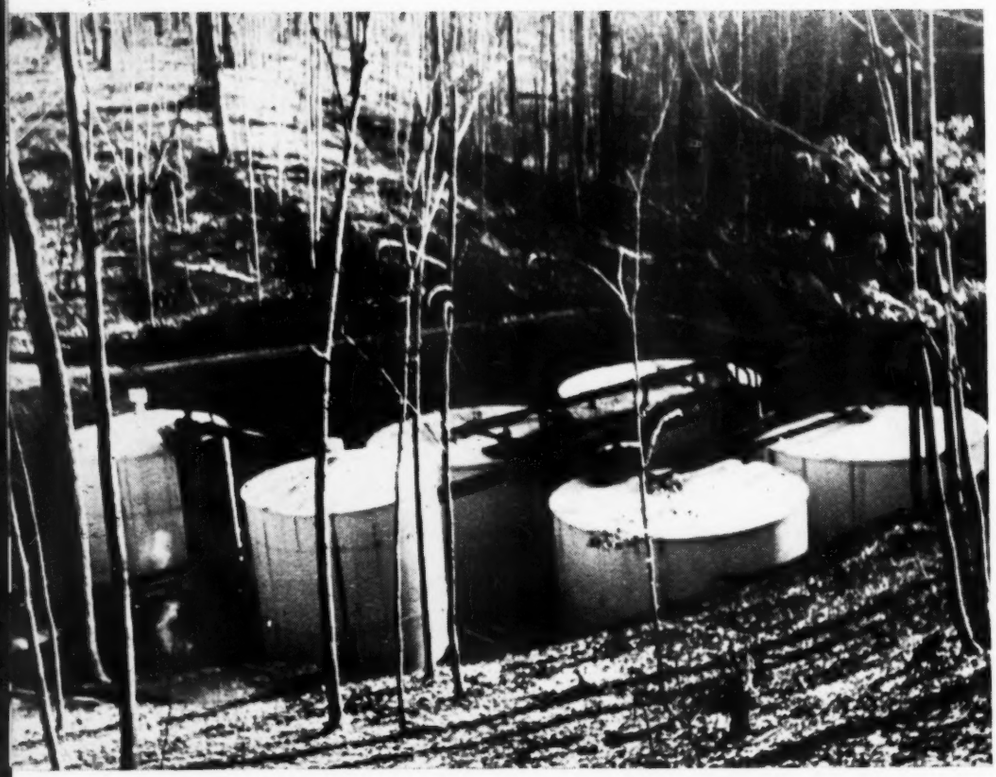
Steaming of tubing, well-head connections, and flow lines becomes necessary, and on some properties elaborate provision is made to do this economically. Steam is conveyed from a central boiler plant to the wells through overhead insulated steam lines. Many of these overhead lines have now been discarded in favor of steam lines laid in a trench with other lines such as flow lines and gas-injection lines from the wells. By having the lines together in a trench, heat lost from the steam line by radiation is gained in part by the oil line and the gas-injection lines; heat losses are thus reduced and more economical use of the steam is obtained.

Treatment at the well by steam may be by injection into a jacket of concentric tubing extending down to the limit of the paraffin deposit.

Another method is to replace at regular intervals the top joints of tubing with clean joints of tubing that are



Interior of compressor station No. 4, West Ghirdoveni, Moreni field



Central oil collecting station

already made up into stands in the derrick. This method when applied to a large group of wells has the disadvantage of a large investment in tubing that is always out of service.

One of the popular and regarded as one of the best, methods for the removal of paraffin deposits is that of making periodical injections of hot oil into the tubing after lifting the plunger and standing valve. The quantity needed for efficient washing varies at different wells, but usually pumping in oil sufficient in quantity to fill the tubing is satisfactory. When this method is used the oil is usually gravitated from a tank set at a higher elevation than the well. This obviates the use of a pump. One tank may be used to serve a group of wells. Oil at a temperature of 212 deg. fahr. (100 deg. centigrade) is generally used. After the hot oil injection the standing valve is lowered into place and pumping resumed, the whole operation taking two to four hours.[2]

Chemicals are also used to remove paraffin deposits. These are usually introduced into the casing by using some form of lubricator. All solvents of this nature must be imported and if large quantities are used they become an item of great expense.

Mechanical scrapers on the sucker rods are also employed for the removal of paraffin deposited in the tubing. These are attached to the upper end of the string of sucker rods at suitable intervals and operate in that part of the tubing string where the deposition of paraffin occurs.

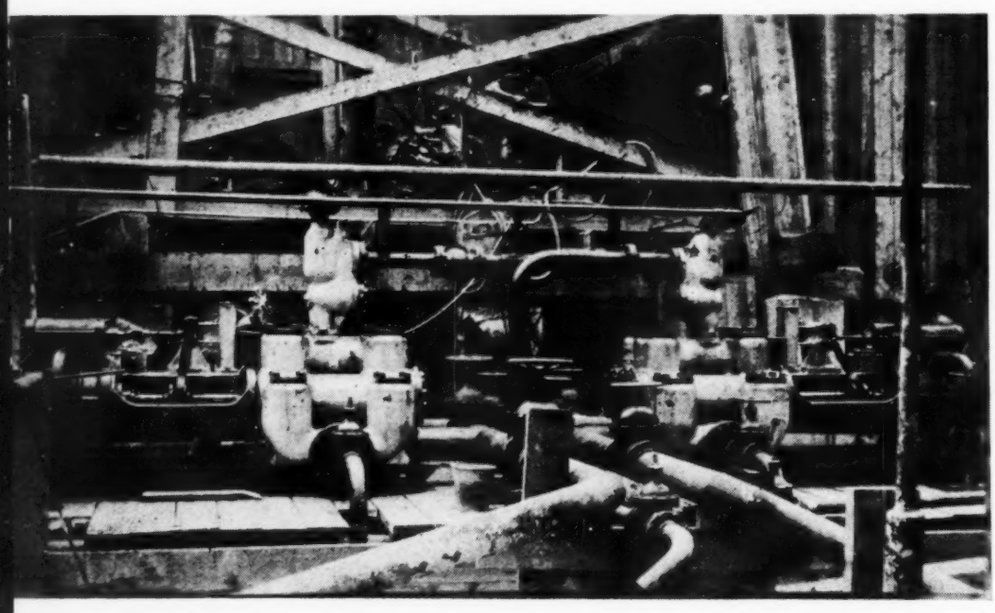
Salt water produced with the oil in Roumania appears to cause no great difficulty from corrosion, but it is found that salt present in the crude gives rise to problems in refining. As most of the oil accumulations in Roumania have some connection with salt plugs it explains the presence of this salt in the crude. Every effort is being made by many of the leading companies to take all necessary steps to prevent an aggravation of this problem and mitigate its evils.

Of the gas-lift systems in use the intermittent flow displacement system is perhaps most widely used.

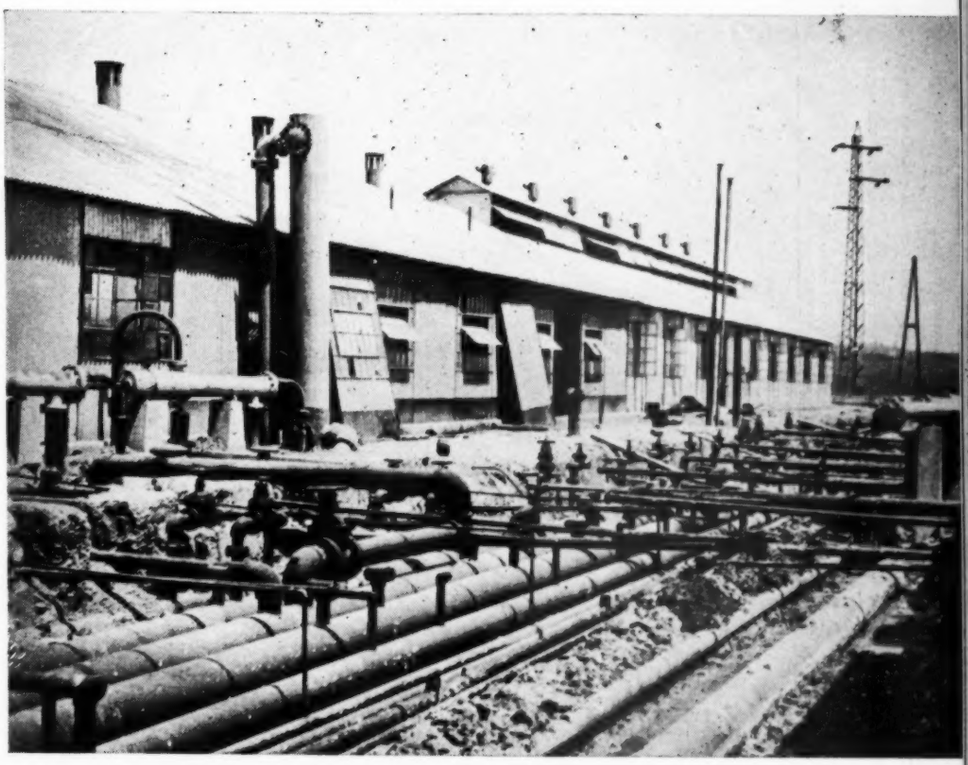
Of the pumping wells many are produced from central powers, both band wheel and gear type powers being in use. In the deeper fields many of the pumping wells are equipped with individual pumping units of modern design. There are some long-stroke modern pumping units in operation. One of these operated at twelve 11-ft. strokes per min. at a depth of 6121 feet. Sucker rods of 1-in., 7/8-in., and 3/4-in. are in use. Combination sucker rod strings are used in some wells.

At one time it was common practice in Roumania to have a crew at each well on certain leases, regardless of how the well was produced. Each well was individually gauged, and had a separate collecting system. This involved considerable equipment such as tanks, pumps, and pipe lines of various sizes for steam, oil, and gas. This arrangement was necessary because of a sliding scale royalty on state leases. Where the conditions are favorable, government authorities now allow each well on such leases to be gauged as often daily as possible for periods long enough to establish a production rate for each well.

This concession by government authorities on gauging wells has per-



Steam slush pumps on a modern rotary rig, Tzintea Hill



Manifolds at compressor station No. 4, West Ghirdoveni

mitted centralizing gathering systems on government leases so that all oil is flowed to a central tank station. In conjunction with this gathering system there is adjacent to the tank battery for pumping oil a central boiler system for heating the paraffinous oil. The oil is reheated before pumping to the pipe line station. There is also a central distribution plant for gas injection wells that are produced by gas-lift.

The central collecting systems as here described are being generally adopted where possible. In older areas an individual well attendant is no longer used. Wells are usually grouped and operated by one crew. This has reduced labor and material costs.

Acreage in many fields is held in small blocks and competitive conditions enter that preclude the efficient practice of reservoir pressure control. Some attempts have been made at reservoir pressure control by restricting production according to a formula devised by company engineers. Control by applying this formula involves determination of the production rate on a selected size choke, the dissolved gas-oil ratio, the flowing gas-oil ratio, and a fixed constant K. Although no outstanding results have been obtained the fact that control by this means has been attempted is regarded as an encouraging sign. Some of the companies take bottom-hole pressures and other data for their own information to aid in improving their producing operations.

Secondary recovery methods are not practiced to any extent.

Advanced petroleum engineering practices are gradually being introduced. Tests on drilling and production equipment are being made by some companies. The analyses of drilling mud and the study of its properties are now being applied in drilling operations. Dynamometer tests are made on pumping wells by some companies, to check their operation. The treatment of emulsions is studied. Bottom-hole pressure surveys, temperature surveys, and the analyses of bottom-hole samples are made by some companies to aid in increasing the efficiency of their operations.

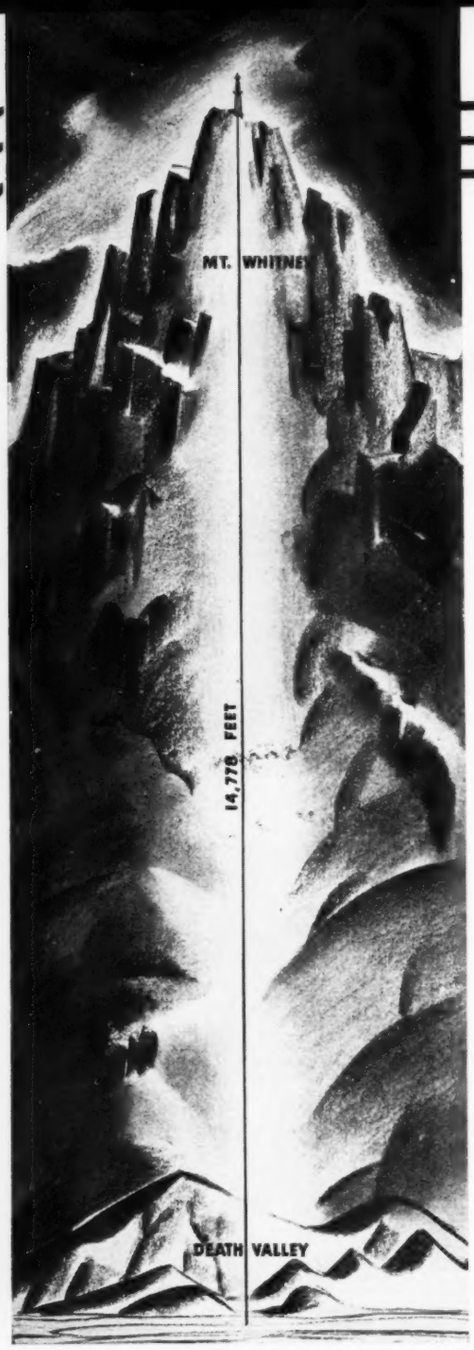
All development operations are regulated by the Mining Department of Roumania. Field development regulations are imposed to which companies must rigidly adhere. These regulations cover the practical aspects of drilling and well completion.

The divided ownership of property makes it difficult to adhere to a well-spacing program that reservoir conditions indicate should be followed. There is a tendency to go to wider spacing because of the conservation of energy that is likely to result.

One of the great difficulties confronting companies is that foreign equipment is subject to high import taxes. This condition interferes with and may preclude selection of equipment of the proper type for efficient operation.

Exploration rights also enter to change the aspect of a development program. The Mining Department officials are torn between satisfying a crying national need for an immediate increase in oil revenues and that of a sincere desire to see that Roumania's oilfields are produced efficiently in order that the greatest ultimate recovery may be procured.

Heavy-duty rotary rig drilling at Tzintea



Imagine a column of drilling mud long enough to extend from the top of Mt. Whitney down through the earth to the level of Death Valley. Subject this nearly 15,000 foot long column of mud to high temperatures and pressures—load it with formation debris which may flocculate it, thicken it, make it abrasive or cause it to gas-cut.

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Book Reviews

Oil and Petroleum Year Book, 1938. Compiled by Walter E. Skinner, 15, Dowgate Hill, Cannon Street, London, E. C. 4, England. 536 pp. Price 10s ($2.50), plus postage.

This edition gives complete particulars concerning 774 companies engaged in producing, transporting, and marketing oil, financing oil development, or directly associated in any way with the oil industry in all parts of the world. During the last two years particulars of 200 companies have been added.

The particulars of each company include the directors and other officials, date established, location of property, or description of business, purchase consideration, oil production, capacity of refineries, capital, dividends, and financial position as disclosed by latest accounts.

Other useful features of the book are the statistical tables showing the world production of crude petroleum for the nine years ended December, 1937, list of trade names of petroleum products marketed by the various companies, a glossary of technical terms and words peculiar to the oil industry, and buyer's guide comprising 224 headings of oilfield and refinery equipment.

* * *

Gravity of Petroleum Oils. The "Practical" Method of Reducing Observed Degrees A.P.I. to Degrees A.P.I. at 60 deg. fahrenheit. Published by J. J. Stephens, Box 1348, Tulsa, Oklahoma. Chart. 1938. Price $2.00 ($1.50 in quantity.)

The tables for oil of observed gravities from 20 to 50 deg., inclusive, of the 1930 booklet edition have been reprinted as a large chart. These tables greatly simplify the work of converting observed gravity at temperatures other than 60 deg. to A.P.I. gravity at 60 degrees. Furthermore, both the old and new methods of interpolation have been included. Complete instructions accompany each chart.

* * *

Asphalt and Allied Substances, by Herbert Abraham. Published by D. Van Nostrand Company, New York, N. Y., 4th Ed., 1938, 1491 pp.

This volume is a comprehensive treatise on the origin and geology of asphalt, its chemistry, mining and preparation, products and their uses, and methods of testing. Beginning with the earliest known use of asphalt in prehistoric time, the book traces the development of the preparation and utilization of asphalt to the latest patented ornamental shingles. The book should interest the refiner, as a producer of asphalt, as well as the builder or contractor, as a user of asphalt products.

* * *

Standards of Heat Exchange Institute: Steam Jet Ejector and Vacuum Cooling Section. Published by Heat Exchange Institute, 90 West St., New York City. 40 pp. 1938. Price, $1.00.

Part One, "Steam Jet Ejectors," covers nomenclature, operating principles, types of assemblies, capacity, and standard accessories and materials of construction.

Part Two, "Test Code for Steam Jet Ejectors," covers motive steam, condensing water, vacuum and pressure measurement, capacity measurement, performance tests, diagrammatic arrangements of apparatus for conducting various tests, standard air nozzle orifices, curves on steam flow, and data on mixtures of air and water vapor.

Part Three, "Steam Jet Vacuum Refrigeration Equipment," covers nomenclature, definitions, performance, construction, standard units, and special types.

Rotary Drilling Handbook, by J. E. Brantly. 2nd ed. Published by Russell Palmer, 412 West Sixth St., Los Angeles, Calif. 350 pp. 1938.

The first 225 pages of this volume are devoted to a general discussion of the factors affecting the efficiency and economy of drilling and completing wells by the rotary method. Every part of the equipment, from power plant to bit, is considered; the general and special features are outlined and different types of equipment are compared.

The second part of the book includes charts and formulas for use in solving particular problems, glossary of terms used, and a general index and an index to tables and formulas. Simple empirical formulas have been given preference over more complicated derivable formulas, as the material included is that which is most generally used by the practical field worker.

* * *

The Science of Petroleum, published by Oxford University Press, 114 Fifth Ave., New York, N. Y. 4 vol., 3131 pp., 1938. Price, $85.00.

Volume 1 describes the origin and accumulation of oil and gas, geological and geophysical prospecting methods, drilling, production, measurement, transportation, and storage.

Volume 2 discusses the physical and chemical properties of petroleum and refined products, analysis and testing methods, history of refining, natural and refinery gases, and distillation.

Volume 3 explains chemical and physical refining methods, solvent extraction, dewaxing, gas pyrolysis and polymerization, cracking, hydrogenation, engineering principles, metallurgy, corrosion, instruments, power and water supply, and fires.

Volume 4 describes products and their utilization, combustion and detonation, and bituminous materials and their products.

J. B. O'Connor Made Director of S. R. Dresser Manufacturing Company

J. B. O'Connor, vice-president and general sales manager, Clark Brothers Company, Olean, New York, has been elected to the board of directors of S. R. Dresser Manufacturing Company, Bradford, Pennsylvania, according to a recent announcement by H. N. Mallon, president.

J. B. O'CONNOR

O'Connor has been associated with Clark Brothers Company since 1927, entering the firm as sales representative, and later advancing to the position he now holds. Clark Brothers Company are well-known manufacturers of gas engines and compressors. S. R. Dresser Manufacturing Company, the parent company, manufactures Dresser pipe couplings and pipe-line repair devices.

Cabot Enlarges Booster Station

Godfrey L. Cabot, Inc., of Olean, New York, are adding to the booster station on their Rochester line another 6-cylinder, 600-hp. Clark right-angle compressor, to enlarge the station's capacity.

Move District Office

The Jeffrey Manufacturing Company, Columbus, Ohio, announces the removal of its Texas district office from Dallas to 6358 Auden Street, Houston, Texas.

T. P. Burke is district manager, and H. F. Adrian, sales engineer.

Running Tour
WITH MEN IN THE INDUSTRY

FRANK A. WATT has been appointed purchasing agent of the Humble Oil and Refining Company, Houston, Texas, to succeed **JOHN A. ROWE,** resigned. Watts formerly was chief engineer of the company's sales department.

LeROY G. SNOW is the new deputy supervisor of the Rocky Mountain Division, U. S. Geological Survey, making his headquarters at Casper, Wyoming. He suceeds **J. R. REEVE,** who has been promoted to supervisor of the Mid-Continent Division at Tulsa, Oklahoma.

F. A. DAVIES, of the California-Texas Oil Company, Ltd., New York, sailed Thursday, October 6th, on the Queen Mary for Bahrein Island on a business trip to the properties of his company. He expects to be gone six months.

G. H. van SENDEN has retired as vice-president in charge of manufacturing after 23 years of service, it has been announced by **S. BELITHER,** president of Shell Oil Company. **F. S. CLULOW** will succeed him. Van Senden became affiliated with Shell in 1915 as superintendent of the Martinez Refinery. He continued with Shell Oil until 1933 when he went to New York as vice-president of Shell Union Oil Corporation. In 1935 he returned to the Pacific Coast to resume his former post of vice-president of Shell Oil.

Clulow, the new vice-president, joined Shell in 1920. After preliminary experience he was made assistant superintendent of Martinez Refinery and continued there for several years. Later he was made manager of the East Chicago Refinery of Shell Petroleum Corporation. He returned to the West Coast in January of this year to become manager of the manufacturing department of Shell Oil Company, the position he held at the time of his appointment as vice president.

HARVEY B. WHITAKER, in charge of the San Antonio, Texas, office of the Bridwell Oil Company, has been transferred to Mattoon, Illinois, and his post in San Antonio assumed by **MORRIS CANNON.**

EARL V. HEWITT is the new general superintendent of production of the Pan American Production Company, Houston, Texas. The appointment was effective October 1st, Hewitt succeeding **C. A. RUSSELL,** who resigned recently to enter business for himself. Hewitt became associated with Pan American in 1935 and at the time of his promotion was assistant general superintendent. **H. R. FUNK,** who has been field foreman at Charenton, Louisiana, was appointed assistant general superintendent. **O. H. EICHELBERGER** takes over the post of field foreman at Charenton.

FELIX MENDOZA, who has been district engineer in the Fitts pool, Oklahoma, for the Magnolia Petroleum Company, sailed recently for Colombia, South America, to assume a government post. Mendoza graduated in 1935 as a civil enginer from the Universidad Nacional, Bogota, Colombia, and soon thereafter came to the United States to attend the University of Oklahoma. He graduated from that institution in 1937 with the degree of petroleum engineer. Since then he has been on the staff of the Magnolia Petroleum Company in the producing, geological, gas plant, and refining departments.

FELIX MENDOZA

J. B. FISHER, secretary of the Kendall Refining Company, Oil City, Pennsylvania, has been elevated to vice-president of the company. He succeeds the late **HOWARD H. GREENE** who was killed in a plane crash September 18. Fisher also will retain his position as secretary of the company.

W. P. HAND has been appointed manager of the San Bernardino Division of the Southern California Gas Company. He succeeds H. C. McAllister, who has retired after 29 years of service with the company.

HARRIS PRUITT has established in Fort Worth, Texas, the new engineering firm of the Harris Pruitt and Company. He formerly was chief engineer of the Texas Pacific Coal and Oil Company.

FRANK LINGAFELTER, Tulsa, Oklahoma, superintendent of production for the Ohio Oil Company, has resigned to enter the drilling contracting business with Burr Williams.

EDWARD L. MOREND, Tampico, Mexico, pipe line superintendent of the Mexican Gulf Oil Company, has returned to his headquarters after a vacation in California and the Northwest.

RECTOR C. BROWN, district foreman at Crane, Texas, for the Magnolia Petroleum Company, has been transferred to St. Elmo, Illinois, where he is superintendent.

EARLE W. GARD, development engineer of the Union Oil Company of California, has been named director of research and development. He will have his offices at company headquarters in Los Angeles.

A. S. BAILEY, vice-president of The Texas Pipe Line Company, has returned to his home in Houston, Texas, from Europe, where he spent most of the summer. While away he attended the wedding of his son in Sweden.

H. L. DAVIS is superintendent of Illinois operations of Williams Bros. Company, pipe line contractors. The company recently opened an office at Flora, Illinois.

LEE R. COWLES, on October 1st, became traffic manager of the Standard Oil Company of Indiana. He succeeds **ROBERT H. McELROY,** who retired.

JOE LEONARD has joined the staff of the Standard Oil Company of New Jersey and sailed recently for Cairo, Egypt. He formerly was with the Standard Oil Company of Louisiana at Shreveport.

NAMED FOR THE *Rugged* RED MAN

UNION WIRE ROPE CORP

AMAZING HARDIHOOD OF THE INDIAN

The American Indian probably exceeded any other race that ever lived, in physical courage and hardihood. To excel in feats of strength and skill and in ability to endure pain and hardship, was his ambition from early boyhood. To these ends, he pursued a rigorous program of self-discipline which, in addition to almost constant physical activity such as hunting, running, swimming, rowing and fighting,—also included floggings, self-inflicted tortures, and long periods of fasting.

It is reported that some of the Indian message carriers could run 100 miles in a day, and that Indian warriors could endure the most inhuman tortures of their enemies without allowing their bodies to flinch or their faces to show a trace of pain.

All UNION Wire Ropes meet all API Specifications

"INDIANA LIKES A *Rugged* WIRE LINE!"

A number of state names were derived from Indian dialects — but Indiana was named for the American Indian, himself. The name, "Indiana", coined by early white settlers, means "Land of the Indians".

Indianians admire hardihood in products, as well as in men. UNION Wire Lines are popular in the Indiana oil and gas fields because of their ruggedness, their superior resistance to wear and tear, their ability to give long service.

The photograph shows a well three miles west of Sullivan, Indiana—drilled by BIG FOUR OIL & GAS COMPANY, INC., of Bridgeport, Illinois. The men, left to right, are: Front row—V. K. Michael, Ohio Oil Co.; Ham Mills; Ralph R. Stealey, driller, Big Four Co.; Herschell Lawson, tool dresser. Back row—Dr. J. G. Jones; Al Lasher; E. C. Wharf; Frank R. Evens, vice-president, Big Four Co.; C. O. Barnett; H. R. Gruber, manager of oil country sales, Union Wire Rope Corp.; E. E. Lewis, Dehydro Co.; L. M. Allison, bookkeeper, Big Four Co.; Ted Seitz; P. E. Taggart, superintendent, Big Four Co.; J. C. Printy, district salesman, Union Wire Rope Corp.

UNION WIRE ROPE CORPORATION

Oil Country Sales Offices: Beacon Bldg., Tulsa, Oklahoma
General Offices and Factory, Kansas City, Mo.

In Mexico: E. O. CHAPA, P. O. Box 604, Tampico, Tamps, Mexico. Stocks at Tampico.

JARECKI MFG. CO.
Distributors: Midcontinent, New Mexico and Eastern Fields.

Export Agents: (except Mexico) LUCEY EXPORT CORP., Woolworth Bldg., New York; Broad St. House, London.

UNION WIRE LINES

The "ULTIMATE LOW COST WIRE ROPE"

LAUGH WITH BARNEY

Edited by BARNEY HORRIGAN

The motorcycle cop drove up beside the car that was holding up the line. "Can't yer go any faster?" he roared.

"Sure, but I don't wanna leave the car."

* * *

Visitor: How's the new swimming pool?

Superintendent of Insane Asylum: Fine! It's become so popular with the patients, especially those that can dive, that I am thinking of having it filled with water.

* * *

He: Where have you been keeping yourself, beautiful?

She: What makes you think I've been keeping myself?

* * *

"Another combination shot," said the coed as she leaned too far over the billiard table.

* * *

Festive One: Whash yer looking for?

Policeman: We're looking for a drowned man.

Festive One: Whash yer want one for?—*The Core Driller.*

* * *

No wonder so many guys are caught with 'em down—a fellow just can't run with anything hanging around his ankles.

* * *

W.P.A. Executive: If we don't figure out a way to spend one hundred and twenty million dollars, we lose our jobs.

Secretary: How about a bridge over the Mississippi—lengthwise?

* * *

Lydia had four children named Eenie, Meenie, Minie and Edgar—she didn't want no Moe.

* * *

Asked to describe the spinal column and a skeleton the sixth grader wrote: "The spinal column is a bunch of bones that run up and down your back, keeping you from being legs all the way up to your neck and a skeleton is a stack of bones with all the people scraped off."—*Bridgeport Bulletin.*

* * *

Many girls have been taken in when they thought they were just being taken out.

* * *

An efficiency expert is one who is smart enough to tell you how to run your business and too smart to start one of his own.

Many a girl has thought herself bitten by the love bug only to find out later that the guy was a louse.

* * *

Then there was the drunk, who, when making a telephone call, received two nickels back when he failed to complete the call, so he played three dollars worth of nickels trying to hit the jack-pot.

* * *

A hick town is the place where a spinster school teacher has lots of pupils, but not much class.

* * *

The elderly Scotch woman applied to the welfare office for an increase in her relief grant. "But, madam," explained the director, "you already draw the limit."

"That may be, but I don't see how I'm going to get along. I can't save a thing on it."

* * *

Versatile

"What the deuce are you doing down there in the cellar?" asked the puzzled rooster.

"Well, if it's any of your business," replied the hen, "I'm laying in a supply of coal."—*Kitty-Kat.*

* * *

We hear that a W.P.A. worker died on the job. They sent for the undertaker and he embalmed seven men before he got the right guy.—*Expanding Circle.*

* * *

"How did you get that bad eye?"

"It's a birth mark."

"What you mean, birth mark?"

"I got in the wrong one last night."

* * *

"Let That Be a Lesson to You"

"You want more money? Why, my boy, I worked three years for $11 a month right in this establishment, and now I'm the owner."

"Well, you see what happened to your boss. No man who treats his help that way can hang on to his business."—*The Yellow Strand.*

* * *

Ephraim: Did you know dat Jonah was three days in de stomach of a whale?

Rastus: Dat ain't much. Mah uncle was longer dan dat in de stomach of a alligator.

Ephraim: Yo' don't say! How long?

Rastus: He's dere yit.

A tramp was sleeping behind the bunker of a golf course when the club secretary, prowling around, kicked him none too gently and ordered him to clear out.

"And who are you?" demanded the tramp.

"I'm the secretary of the club," said the official.

"Well," replied the tramp, "that's no way to get new members."

* * *

A high class town is one where they have two bread lines—one for white and one for rye.

* * *

The following story concerns a motorist whose car had come to a sudden standstill on a country road.

The motorist descended, quickly diagnosed the trouble, and then applied at a neighboring cottage for assistance.

"Pardon me," he said to the old lady who answered his knock, "do you by chance possess any lubricating oil?"

The old lady shook her head.

"Any oil will do," said the motorist hopefully, "castor oil if you have any."

"I ain't got it," said the old lady regretfully, "but I could fix you up a dose of salts."

* * *

The boy and girl were out on the highway when the car broke down. He didn't seem to mind and wanted to make love. "My kisses will put new life in you," he said.

"Then for goodness sake get out and kiss the car," she replied.

* * *

Mandy: At first it was love. He fascinated me—and I kissed him!

Liza: Yeah, I know, and then he began to unfascinate you — and you slapped him!

* * *

"Are you good at riddles?"

"Yeh."

"What's the difference between a woman and a cow in a pasture?"

"I don't know. I never had a cow in a pasture."

* * *

The world's best after dinner speech: "Waiter, give me both checks."

* * *

When you tighten your belt, it's a recession. When you have no belt to tighten, it's a depression. When you have no pants to hold, it's a panic.—*Louis Allis Messenger.*

YOUNGSTOWN'S

New Forged Steel

UNION CHECK VALVES

Spring Controlled

PETRO and HANDLE-BAR

Built Especially for Oil Country Service, Offer Long Life, Corrosion Resistance and Free Flow

Youngstown has built a special forged steel Union Check Valve for the oil country and put into it everything that tough service and corrosive liquids could demand. Forged steel of course, the Petro Union Check Valve is spring controlled and will stand 600 lbs. steam, or 2000 lbs. cold, working pressures. Valve body and male end are phosphated to increase acid corrosion resistance. Body is Vanadium Cast Steel with a tensile strength of 103,000 lbs. per square inch. Valve poppet and seat are U.S. Navy specification for corrosive resistant bronze and both poppet seat and spring are chrome plated as an extra protection against abrasion. The nut is rust and spark proofed with nut threads permanently lubricated with Udylite Cadmium.

The Petro Union Check Valve will handle full pipe capacity, can be used in any position. On all steam, water, air, oil, gas, and chemical service in the oil industry its long service is assured by a tongue and groove joint with a copper jacket asbestos gasket that will allow unlimited break down and make up without losing its seat seal. The Petro Union Check Valve is an oil man's check valve. Complete inspection of poppet, seat and spring can be made without removing the valve from the line.

The spring controls the opening and closing of the poppet in accordance with the velocity of the flow. It is not affected by sudden fluctuation of flow or back pressures. It will not pound. The Check valve may also be had to the same specifications but with handlebar union nut as illustrated. For complete information write today for the name of your nearest dealer to Union Division P.O. Box G, Chicago, Illinois

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QUALITY TRADE MARK YOUNGSTOWN SERVICE

MACHINERY and EQUIPMENT

National Unit Pumper

THE National Supply Company, Toledo, Ohio, announces the Type TU140G-JD14T National Unit Pumper made for use in the shallower fields.

This unit is of the twin-crank design and is similar in general appearances to the types of pumpers used for deeper work. It has a 7.44 nominal hp. rating at 20 s.p.m. and a double reduction gear having a ratio of 24.9 allows the use of all types of oil-country prime movers including those operating at high speeds. Maximum polished rod stroke is 32 in. and the safe working load of the walking beam is 6170 pounds (A.P.I.).

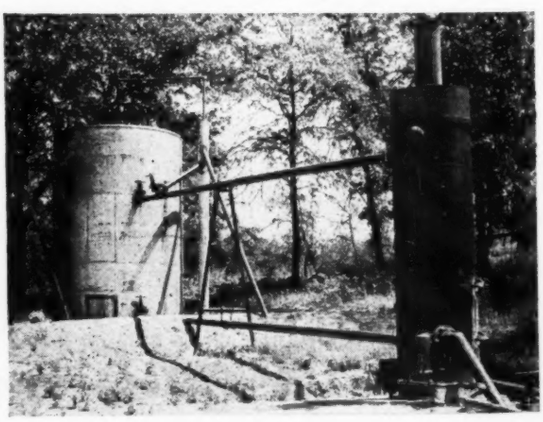
This unit has a compact, integral all-welded construction, which achieves rated capacity with less weight and makes it possible to offer a twin-crank pumper of its design and capacity at a low first cost, the manufacturers state. The frame, gear case, samson post, and saddle bearing bushings form an all-welded, integral unit without bolts or rivets. The case and post are welded to the base and are reinforced by two diagonal angles running from the post to the frame. The gear case is bored at one setting after the entire welded assembly is made to insure vertical and horizontal alignment of shafts.

The walking beam is a 10¼-in. CB section and has an extension for beam counterweights. Counterweights are used in increments from one to seven giving a counterweight effect at maximum polished rod stroke of 1281 to 4036 pounds. A link-type polished rod hanger of a design thoroughly proved in pumping service is regular equipment, it is asserted. The linkage closely approximates straight lift and is simple in construction and easy to lubricate. A hanger of the arc type is available on special order. Ample clearance for servicing operations without disconnecting the pitmans is procured by a removable type beam hanger head.

Two sizes of plain cranks give a range of strokes at the polished rod of 18 in. to 24 in. and 24 in. to 32 in., respectively. Reduction gears are single helical type of favorable proportions for long wear and are carried on well-supported shafts of ample size. All shafts are Timken roller bearing equipped. Gears run in oil and gear shaft bearings are lubricated by oil wipers in the top of the gear case or by splash. Bearings are made dust- and oil-tight by Perfect oil seals. Saddle, beam pitman, and wrist pin bearings are of the oil- and dust-proof oil-bath type.

B. S. & B. Double-Unit Treating System

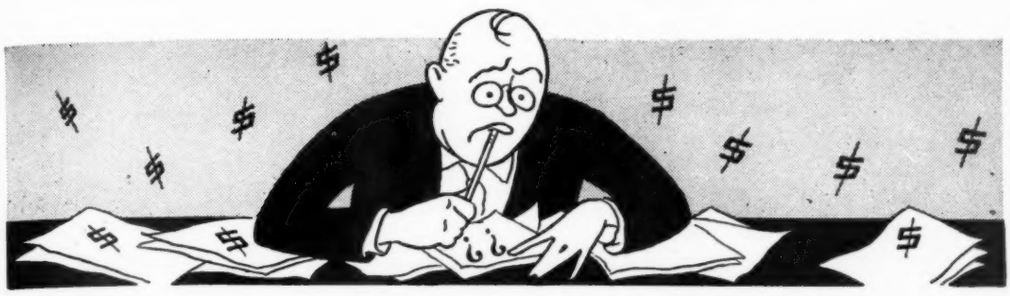
BLACK, Sivalls and Bryson, Inc., Oklahoma City, Oklahoma, announces a new double-unit treating system. The unit incorporates an efficient heater, removed from the treating tank, for heating thermosiphon fashion and said to reduce fire hazard and repair costs; a wash tank to fit fluid volume and treating conditions having an ingenious built-in partitioned inside flume and B. S. & B. inverted sloping pan baffles for prolonged washing and efficient treating.



The treating tank may be equipped with flat bottom or coned deck for low-pressure treating (16 oz.), or may be equipped with flanged and dished heads for high-pressure treating (25 lb.). The manufacturer asserts that treating under pressure minimizes evaporation losses. A heavy duty horizontal tubular heater for large volumes of corrosive fluid, and a vertical fire-tube heater for small volume heating loads, also are provided.

WHAT IS THE COST?

YOU SHOULD KNOW BEFORE YOU DRILL!



THERE is no other reason to prefer one method of drilling to another, except the reason of *overall economy*.

You may need cable tools. You may need a rotary outfit. Or a combination of both. Specific, competent analysis is necessary before you can make your decision.

Depth, character of foundations both for drilling and production possibilities, accurate appraisal and analysis of the time factor and its relation to cost — these all vary in different cases. They all need to be considered for each case independently, if unnecessary waste is to be avoided.

Whatever drilling method you may use, reliable equipment and a capable crew are necessary. An analysis assuring these, with your own requirements definitely in view, will enable you to compare, decide, and then proceed, knowing that the method you adopt is the best for your particular job.

Cable-system drilling is economical only with good equipment, properly maintained, and good equipment includes good tools. *Spang Cable Tools* are the standard of comparison for good tools the world over.

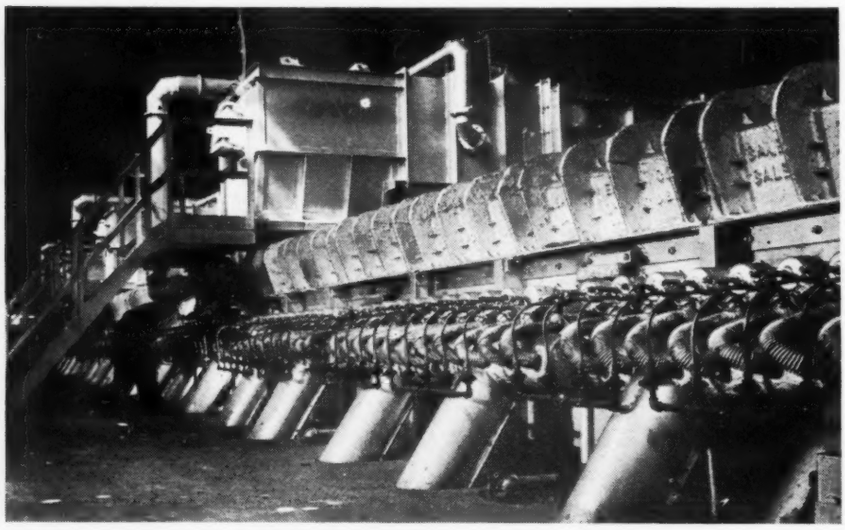
Fig. 524 Fig. 511

SPANG CABLE TOOLS The HIGHER STANDARD

SPANG AND COMPANY, BUTLER, PA.

Manufacturing Continuous Weld Pipe

THE mills of Spang Chalfant, Inc., at Etna, Pennsylvania, are producing for the petroleum industry approximately 6000 tons of continuous weld pipe per month. The design of the pipe is in accordance with the improved Fretz-Moon patents, is of the buttweld type, and in size is of ½ in. to 3 in. I.D.



Continuous heating furnace

Pipe ready for testing and finishing

In manufacturing continuous weld pipe Spang Chalfant employs a process involving the use of three controlled heat zones. On the dead end zone a temperature of 1900 deg. fahr. is maintained and on the discharge end zone a temperature of 2900 deg. fahrenheit. In the recuperators preheated air is used for combustion. Each recuperator has 28 cast-iron elements and 21 chrome-steel elements.

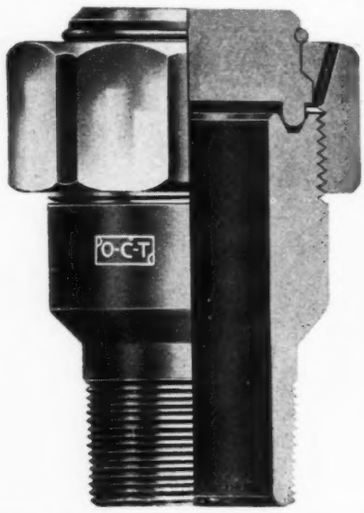
A feature of the manufacturing process is the method of handling the skelp. At no time does the skelp come in contact with the bottom of the furnace, thus keeping it free from furnace contamination. Rolls in the dead end zone of the furnace are of heat-resisting alloy and in the rest of the furnace water-cooled skids are employed. Skelp reels are of 35 to 38 in. diameter, weigh 600 to 1800 lb. each, and contain 185 to 550 ft. of skelp each.

Heat control, automatic welding, and the continuous process of manufacture result in a product of uniform weld, as well as one of high bursting strength, the manufacturers assert.

O-C-T Quick-Change Choke Adapter

OIL Center Tool Company, Houston, Texas, is now offering to the trade a Quick-Change Choke Adapter, which, according to the manufacturer, is designed to eliminate the hazard caused by threaded bull plugs.

This O-C-T adapter, shown herewith in cross-section, is installed on the Christmas tree in the same manner as a bull plug, but instead of breaking-out the tapered thread connection each time it becomes necessary to change the positive choke, the straight thread connection between the hexagon nut cap and body of the adapter is broken. According to the manufacturer, this straight thread may be broken and re-made as often as desired without damaging the threads. The connection between the cap and body of the adapter is machined to a loose fit, and can be made up by hand. One turn with a wrench applies sufficient pressure on the ground joint seat to effect a seal. This loose, straight thread definitely eliminates galling and freezing, it is asserted.



The O-C-T adapter, drilled for ½-in. pressure gauge, is recommended for use as the top connection on Christmas trees to facilitate taking of bottom-hole pressures. The hexagon nut cap can be removed easily and quickly without strain on the Christmas tree. An O-C-T adapter for connecting the bottom-hole pressure-taking equipment to the tree is also available.

A small port is provided in the hexagon nut cap of the adapter to relieve trapped gas and oil upon release of the cap. The adapter is made of forged steel; 2-in. and 2½-in. sizes made in 6000-lb. test; 3-in. and 4-in. sizes available in test pressures to 10,000 pounds.

New Crawler Tread on Buckeye Excavators

AN important development in crawler traction design is being used on Buckeye Clipper Convertible Excavators, constructed by The Buckeye Traction Ditcher Company, Findlay, Ohio.

The new crawler tread is a patented improvement having, according to the manufacturers, several advantages over other treads now in use. One point that all will appreciate is the absolute freedom from clogging. As shown by the

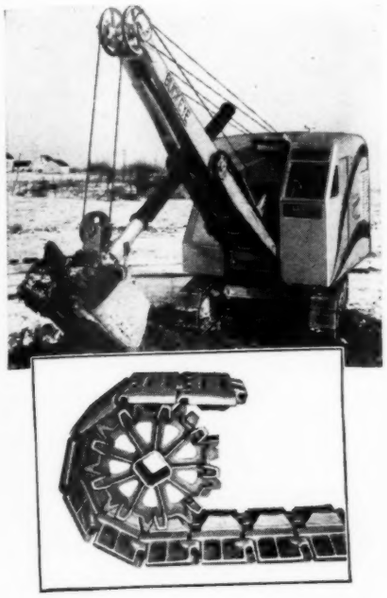


photo herewith, there are no pockets in the tread where loose materials can lodge. The single lug in the center and the wide roller track on each side of the lug give a positively non-clogging surface, it is stated.

As the bearing surface on the top of the lug is cast to a radius similar to that of the sprocket rim, there is little wear on the sprocket rim where the load is carried. This bearing surface will not wear out of pitch and keeps the treads in a true pitch circle. This feature of the new tread is a patented improvement found only in this crawler, it is asserted.

Another advantage of this design is the manner in which the treads fold around the tooth on the sprocket, with no rubbing of sprocket teeth in or out of engagement. This confines wear on the teeth to drive pressure. Relatively high-speed operation is possible without excessive noise. The new crawler is now standard equipment on all Buckeye Clipper Excavators, and is constructed exclusively by the Buckeye Traction Ditcher Company.

Rector Stripper Type Tubinghead

A NEW type stripper tubinghead has been introduced by Rector Well Equipment Company, Fort Worth, Texas, manufacturer of the Rectorhead. This head, which is designated as "SSC" and "SSS," is built on the series 600 A.P.I. flange and is offered in 7-in. and smaller casing size. It is made in either S.A.E. 3130 chrome-nickel cast steel or alloy cast iron.

This new Rectorhead differs from the conventional stripper heads in that provision is made for the use of two neoprene strippers. When conditions warrant, the addition of a second stripper serves as an extra safeguard. Also, when the first stripper becomes worn and would ordinarily need replacing a second can be added without removing the first.

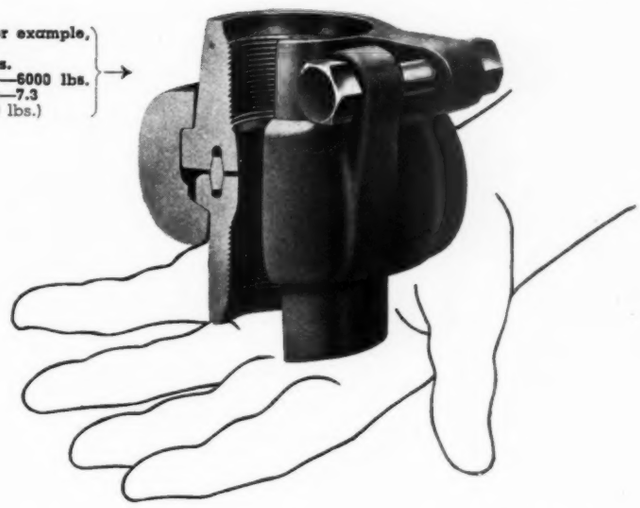
After the tubing has been run and landed, the top stripper is replaced by a set of slips, for suspension, and packing gland and packing for a seal above the slips. The packing is distorted independent of the slips so that it will continue to seal regardless of any settling of the slips.

You'll see this

HELPFUL HANDFUL

the World over!

EFFICIENT! For example, the 2" size:
Weighs 12 lbs.
Test Pressure—6000 lbs.
Safety Factor—7.3
(14.3 at 3000 lbs.)



Revolutionary! That was the one-word description for UNIBOLT a few years ago when multi-bolt flange unions and threaded couplings were still the latest thing in pipe connections. The idea sounded almost too good to be true . . . applying pressure to a single bolt to effect a quick, leak-proof seal for high pressures and temperatures; more metal in direct shear but far less weight; no time-consuming circles of bolts; complete interchangeability of parts that resulted in maximum salvage. The idea clicked, and it's still clicking . . . thanks to progressive operators the World over whose generous acceptance of UNIBOLT Couplings has prompted us to apply the same time and money saving coupling principle to high pressure steel Tees, Crosses, Adjustable Chokes and Flexible Ball Joints, all of which are now available to the oil industry.

Descriptive literature on all UNIBOLT products is yours for the asking.

THORNHILL-CRAVER COMPANY, INC.

HOUSTON, TEXAS, U. S. A.

UNIBOLT
(TRADE MARK REGISTERED U. S. PATENT OFFICE)
THE ONE BOLT COUPLING

Security Liner Setting Tool

THE Security Engineering Company, Inc., Whittier, California, has announced the development of a new type liner setting tool that incorporates an unusual and what the manufacturer states is a foolproof releasing action. The back-off connection between the liner and run-in string is of the conventional wide thread, left-handed type but the unusual features of this setting tool are the devices that prevent the liner from rotating while the back-off operation is in progress and the floating head that takes the weight off the releasing thread. The Security Liner Setting Tool can be used to run both light and heavy liners, or other similar equipment, with the certainty that release can be effected, it is asserted.

The tool consists essentially of a mandrel and a regular tool joint connection on the upper end and a ball bearing thrust washer assembly on the lower end. The upper half of this mandrel between the tool joint and thrust washer has a square cross-section, and the floating head, having a square hole through it, is free to move upward and downward on this squared section. This floating head carries the conventional left-hand back-off connection from which the liner is supported by means of a liner adapter.

The assembly is run in the hole in the conventional manner and when the liner strikes bottom the floating head (to which the liner is fastened) slides upward on the mandrel, thereby removing all weight from the releasing thread. As the run-in string is lowered farther the thrust bearing on the end of the mandrel seats on a shoulder provided for it in the adapter. This permits the full weight of the run-in string to be placed on the liner, thus locking it against rotation, and at the same time preventing any weight being placed on the back-off thread. Then the liner is positively held in position while the run-in string is backed-off by rotating to the right. It is not necessary to raise the run-in string while releasing, because the floating head is free to move up the squared section of the mandrel as the threads disengage. The entire operation is under positive control of the operator at all times.

Other important engineering features of this tool include accommodation for a tail pipe in the end of the mandrel, and a cup-type packing assembly between the floating head and mandrel. These features assure good cementing jobs, permitting the cement to be discharged at the proper place and safeguarding against leakage around the floating head even under high-pressure cementing operations, it is asserted.

The Security Liner Setting Tool is made in a wide range of sizes. Detailed information may be obtained by writing to Security Engineering Company, Inc., Whittier, California.

Granco Pump

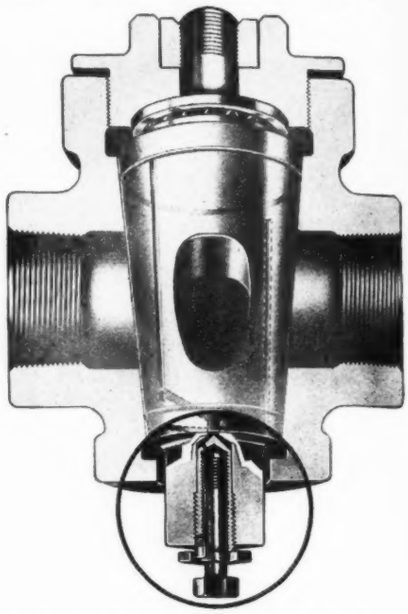
TANK truck builders and operators will be interested in the new 3-in. Granco pump being manufactured by Granco Equipment, Inc. This new unit delivers 300 gal. of fluid per minute, weighs but 171 lb., and operates at a speed of 600 revolutions per minute. The exclusive Granberg rotor

is said to give a high dry suction and the flow is smooth and non-pulsating. Outboard bearing and silent relief valve are built as integral parts of the equipent. The pump is bronze fitted, has 3-in. flanged ports, and operates in either direction. Further details may be obtained from Granberg Equipment, Inc., 4068 Holden Street, Oakland, California.

Mechanical Device for Plug Valve Lubrication

A NEW device to eliminate gas or fluid leakage during plug valve lubrication has been announced by MacClatchie Manufacturing Company, Compton, California. This exclusive MacClatchie feature, known as "Lubricheck," is standard equipment on all new MacClatchie "Hydro-Seal" plug valves, and the only mechanical means of plug valve lubrication on the market, according to the manufacturers. It is designed to give longer wearing life to the valve through positive lubricating action and simple operation, and to eliminate the danger of regreasing plug valves under pressure.

"Lubricheck" consists essentially of a tapered seal that seats against the opening of the lubricating chamber and closes off gas or fluid when the lubricating screw is removed. The tapered seal is equipped with left-hand threads on its outer surface, and less than a quarter turn tightens the seal



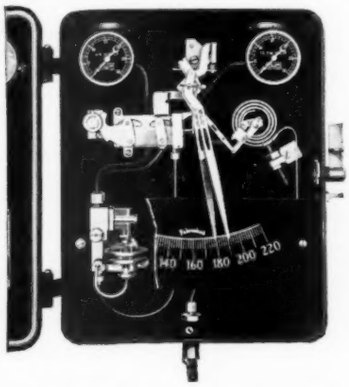
against the seat. As the right-hand lube screw, situated inside the seal, is removed, the friction obtained serves to further tighten the seal against the seat, thus making possible a fluid-tight seal even under extremely high operating pressures, it is asserted. To lubricate, a MacClatchie grease stick is inserted, the lube screw replaced and tightened. A turn to the right automatically loosens the seal of the "Lubricheck" and opens the grease channels. Grease is then forced into the channels and lubricates the entire body and plug of the valve.

Simple construction of "Lubricheck" eliminates quick wearing parts that often do not thoroughly seal off the grease chamber and therefore allow line pressure to force the grease out of the valve when lubricating, it is stated. No sand or mud can interfere with proper operation of the "Lubricheck," and quick easy adjustment, or complete removal, of the lube screw can be accomplished with no gas or fluid leakage, it is said.

MacClatchie "Hydro-Seal" plug valves, equipped with "Lubricheck," are available in many sizes for field and pipe line operations, in screwed, flanged, or union ends, and hand or gear operated.

Direct-Set Indicating Controller

C. J. Tagliabue Manufacturing Company, Brooklyn, New York, announces the development of a new Direct-Set Indicating Controller,



Model No. 9-TIC for temperature and Model No. 9-PIC for pressure.

The manufacturer asserts these instruments are designed for ruggedness and operating convenience and are in a strong weather-proof aluminum case finished with black enamel and chromium. Basically, all the latest Tag developments include the interchangeable calibrated tube system, safety link for range protection, pointer arm brackets having bearings at each end, and all important parts of stainless steel.

These Direct-Set Indicating Controllers can be supplied in two types: "On-Off" or "Throttling." The "On-Off" controller will open the diaphragm if the temperature is slightly below the setting point, and will close the valve if the temperature rises to slightly above. The "Throttling" type is identical to the "On-Off" design except for the flapper mechanism. This instrument utilizes an adjustable flapper that provides a convenient and exacting sensitivity adjustment from hair line to 100 percent throttling range.

The Tag "On-Off" controller and the Tag "Throttling" controller have the direct-set feature. Both the white control pointer and the red setting pointer indicate on the 5½-in. graduated scale, thus offering a clear, direct reading for checking control performance.

The company has published a new bulletin, No. 1175, which describes both the "On-Off" and "Throttling" types of this Tag direct-set indicating controller line, and a copy will be sent free upon request.

Air-O-Line Furnace Pressure Controller

THE Brown Instrument Company, Philadelphia, Pennsylvania, announces the development of their Air-o-Line Furnace Pressure Controller. Long past its pioneering stage, this instrument is applicable for controlling any pressure in the range from minus 5.0 in. of water to plus 5.0 in. of water, the manufacturers state.

The controller is essentially a sensitive, inverted-bell type draft indicator combined with the Brown Air-o-Line Control Unit. Automatic reset and fully adjustable throttling range prevent the furnace pressure from lining out at some point other than the control point and eliminate over-correcting and cycling, it is asserted.

This instrument has consistently held furnace pressures within plus or minus .002 in. of water on a scale span of 0.2 in. of water, it is stated. Not only is it accurate but it is practically instantaneous in operation, as the pointer will move 10 percent of the total range in one second, and 100 percent of the total range in three seconds, the makers assert.

The Air-o-Line Furnace Pressure

Controller is adaptable to installation on all types of furnaces, stills, kilns, ovens, and similar equipment where low differential or static pressure must be maintained.

Valves to latest Oil Industry Standards
GUN-METAL GATE and STOP VALVES
for general purposes
CAST-IRON (semi-steel)—ditto, ditto
CAST and FORGED STEEL VALVES
for high pressures and temperatures
NEWMAN-MILLIKEN GLANDLESS LUBRICATED PLUG VALVES in GUN-METAL, CAST-IRON (semi-steel) and CAST STEEL. RECTANGULAR and ROUND ports.
for working pressures
to 3,000 lbs. per square inch
Newman, Hender & Co. Ltd
WOODCHESTER GLOS. ENGLAND

Consolidated's 2500-Lb. Safety Valve

THE Consolidated Safety Valve Division of Manning, Maxwell and Moore, Inc., Bridgeport, Connecticut, announces the completion of a new line of safety valves for elevated pressures and temperatures (2500 lb. at 1000 deg. fahrenheit).

Special alloy steels having low coefficients of expansion have been selected for the bodies, bonnets, springs, and trim so that these valves will provide the same safe performance at this new high in operating conditions that is regularly produced in safety valves for 300-lb. boilers, it is stated.

J & L Seamless Bell and Spigot Casing

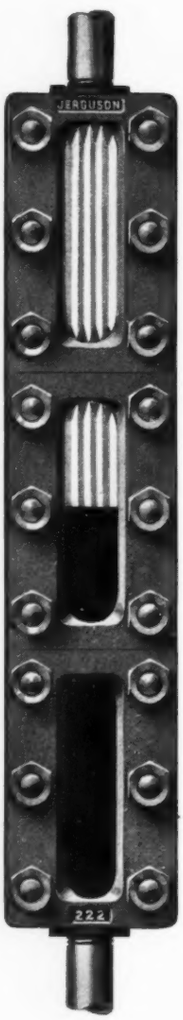
THE Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania, announces the addition of a seamless bell and spigot casing to its present line of oil-country products. This casing, made for welding in the well, features exclusively a die-forged bell.

This new type bell is formed by upsetting the casing instead of by the conventional expansion operation. This die-forging operation forms a heavier bell wall, increases the effective welding area, and assures a concentric correct diameter that by its uniformity makes possible easy stabbing and helps to maintain true alignment of the bell and spigot during welding, the manufacturers state.

The die-forging operation also provides a gentle slope or shoulder from bell to pipe wall that aids in relieving internal stresses arising from expansion during welding and transmits loads away from the joint while in service. In addition, the steel used in the manufacture of the new casing is of a grade especially selected for its welding properties.

A series of full section tensile tests shows that most joints are as strong as the pipe itself, joint efficiency being 96 percent to 100 percent. The new J & L bell and spigot casing is available in sizes ranging from 5½ in. O.D., to 10¾ in. O.D., inclusive.

JERGUSON



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Jerguson Reflex and Transparent (thru vision) Gages have been noted for over 30 years for accuracy and dependability.

Reflex Gages indicate the liquid level, no matter what the color of the liquid. Ideal for tanks, towers, stills, etc., because the . . .

Empty space shows
WHITE

Liquid level appears
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Jerguson Transparent (thru vision) Gages for showing color and density of liquids, are also noted for their accuracy and dependence.

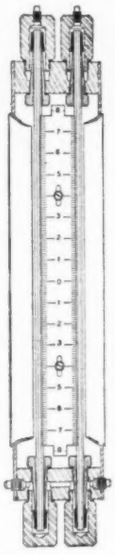
Jerguson Gages are Best
by Every Real Test

Catalog on Request

Jerguson Gage & Valve Co.
89 FELLSWAY
SOMERVILLE MASSACHUSETTS

Packless Type High-Pressure Manometer Seals Without Strain on Tubes

A NEW straight tube, high-pressure manometer suitable for pressures to 1000 lb. is being introduced by the Daniel Orifice Fitting Company. The design of this new Wilcox Manometer permits the use of straight tubes that are sealed against leakage by synthetic rubber sleeves, thus eliminating strain or stresses in the glass. The construction eliminates stuffing boxes and provides a compensating seal under pressure.

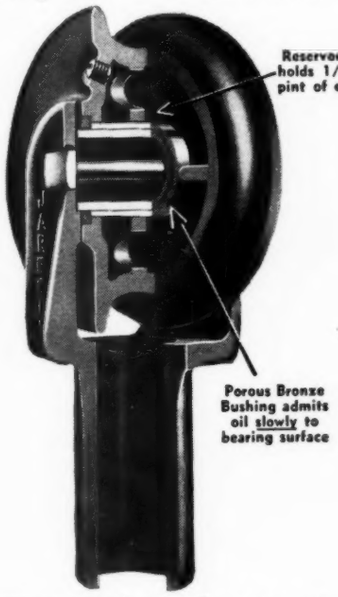


As there is no U-bend and only the slightest contact between glass and metal parts, there is no distortion of the tubes when seal is made, the manufacturer states. Every part is easily accessible, impervious to gas, oil, gasoline, etc., and easily cleaned, it is asserted. If glass is accidentally broken, only one side need be replaced. Full details of the Wilcox Manometer are available from the Daniel Orifice Fitting Company, Department 117-K, 3352 Union Pacific Avenue, Los Angeles, California.

"Jarco" Pull Rod Carrier

THE Jarecki Manufacturing Company recently introduced its new "Jarco" Pull Rod Carrier. The oil reservoir of this new carrier is situated within the wheel, and holds 1/6 pint of SAE-10, which, according to R. W. Hill, engineer for Jarecki at Tulsa, is sufficient oil to last at least six months. From this reservoir the oil feeds slowly through the patented porous bronze bushing to the shaft.

Other features of the new "Jarco" Pull Rod Carrier include: Felt retainers that prevent rain and dust from reaching bearing; ground finish steel tubular shaft of 1¼-in. diameter, resting on bosses cast in frame, and clamped in place by ⅜-in. bolt; cast-iron wheel of 3¾-in. diameter, which is hollow to provide an oil reservoir; and malleable-iron frame ribbed for high strength and low weight and having webs on the lower section to



prevent twisting in the 2-in. rod line post.

A bulletin describing this new pull rod carrier may be obtained by writing the Tulsa, Oklahoma, office of the manufacturer.

G-E 150-Amp. D-C. Arc-Welder

A NEW 150-amp. d-c. single-operator arc-welder has been announced by General Electric Company, Schenectady, New York, which further extends its line into the field of light-gauge work. The new equipment, because of its high, instantaneous recovery of voltage, prevents arc pop-outs at all points in its wide welding range with any good bare, lightly-coated, or heavily-coated electrode, the makers assert. Its stability prevents excessive current surges, thus avoiding excessive spatter loss and sticking of the electrode, it is stated.

Any welding current within its entire range can be quickly obtained by means of a three-point selector switch and an easily operated dial for intermediate adjustment. Additional assurance of dependable operation is provided by a reliable means of self-excitation. Isothermic overload protection permits the equipment to carry maximum safe overloads without danger of burnouts and without unnecessary interruptions on harmless overloads.

The new d-c. equipment is rated 150 amp. at 25 volts and its range of adjustments varies from 20 to 200 amp. at 25 volts.

THREE important steps in making J-M 420 Rotary Lining are shown in the photo above.

The "cabled" asbestos yarn at the extreme right has been specially processed for extra strength. It is tightly woven into a dense, compact fabric; compressed and impregnated with a newly developed compound that has high resistance to heat. The result is a lining that is giving unusual service on rotary brakes. J-M 420 Rotary Lining has these important advantages:

UNUSUALLY EVEN FEED-OFF, giving better control of drilling . . . **HIGHER BRAKING EFFICIENCY,** even at extreme temperatures caused by heavy loads . . . **LONGER LIFE** under any conditions . . . **LESS SCORING OF DRUMS,** giving longer drum life.

In the short time since the new J-M 420 was introduced, this rugged, lasting lining has sold both owner and driller on its superior braking performance. For full details on J-M 420 Rotary Lining and on all J-M Friction Materials, write Johns-Manville, 22 East 40th Street, New York City.

Johns-Manville **420 ROTARY LINING**

Committees Appointed for Next Houston Oil Show

Plans for the 1939 Oil Show at Houston have been further advanced by the recent appointment of committees to handle the various departmental activities that have become important features of the Oil-World Exposition. Although the next Exposition will not be held until April 24-29, 1939, Ed Lenzner, general manager of the Oil-World Exposition, advises that the actual work of the various committees will be started at once so that complete plans of each can be made well in advance and the work of the different departments coördinated most effectively.

The General Program Committee chairman is Joe Russell of Gulf Oil Corporation and the Drilling and Production Committee chairman is George Corless of Humble Oil and Refining Company. Ed Lenzner will serve as assistant chairman of both and the chairman of each will appoint necessary members to carry on the work.

The other committees are: Refinery Committee: W. H. Curtin, W. H. Curtin and Company, chairman; Ed Lenzner, assistant chairman; O. E. Berg, Babcock and Wilcox Tube Company; M. N. Dannenbaum, M. N. Dannenbaum Company; R. L. Mallory, Brown Instrument Company; Joe Miller, Humble Oil and Refining Company; Joe Peddie, Maintenance Engineering Corporation; George Reid, editor, The Refiner; J. L. Finley, Humble Oil and Refining Company; L. G. Marsh, Taylor Instrument Company; G. B. Lane, the Foxboro Company; H. M. Stewart, Humble Oil and Refining Company.

Conference on Refinery Laboratory Procedures: K. H. Clough, W. H. Curtin and Company, sub-chairman; Dr. F. W. Jessen, Humble Oil and Refining Company; Fred W. Karl, Gulf Oil Corporation; R. C. Rich, Shell Petroleum Corporation; A. R. Rickards, Sinclair Refining Company; E. W. Gardner, The Texas Company; W. F. Fulton, United Gas System.

Petroleum Safety Committee: J. J. Delahide, B. F. McDonald Company, chairman; Ed Lenzner, assistant chairman; R. B. Roaper, Humble Oil and Refining Company; C. A. Miller, The Texas Company; C. L. Hightower, United Gas System; P. E. Keegan, Shell Petroleum Corporation; F. P. Werner, American Petroleum Company; Lee Conners, The Texas Company; H. L. Rankin, Gulf Oil Corporation; Geo. Gruber, Mine Safety Appliances Company; R. H. Horde, Shell Petroleum Corporation; T. S. Maffitt, Houston Oil Company; Wm. Grant, Humble Oil and Refining Company; Claude Liles, Magnolia Petroleum Company; C. W. Coleman, Gulf Refining Company; Bob Cox, American Optical Company; Donn Cross, Accident Prevention Company; J. L. Manes, Sun Oil Company; J. L. Risinger, Magnolia Petroleum Company; E. W. Breeland, Lone Star Gas Company; H. B. Williams, Pan American Petroleum Company; Bob Skelton, American Red Cross; G. M. Kintz, engineer, U. S. Bureau of Mines.

Entertainment Committee and Oil Men's Banquet Committee: Frank Carothers, Norvell-Wilder Supply Company, chairman; Ed Lenzner, assistant chairman; T. L. Fontaine, Humble Oil and Refining Company; O. S. Cummings, Houston Oil Company; S. T. Childress, Rio Bravo Oil Company; Robert J. Miller, Robt. J. Miller Company; George O'Leary, Houston Oilfield Material Company.

Foreign Dinner Committee: R. L. Dudley, Gulf Publishing Company, chairman; Ed Lenzner, assistant chairman. Other members will be appointed later.

Transport Committee: Motor transportation division of oil companies will have the following members: Leo New, United Gas System, chairman; E. B.

Wins Quick, Widespread Acceptance for Solving Troublesome Leak Problems

Patent Pending
1-Gal. size shown here. Sold also in other handy sizes.

Since RECTORSEAL, the Positive Leak Preventer, was placed on the market 5 months ago it has proved itself to be the outstanding leak preventer on the following applications.

RUNNING CASING AND TUBING
(Treating collar threads)
DRILLING RIG CONNECTIONS
(Mud, Oil, Water and Steam Lines)
SEPARATOR AND FLOW LINE CONNECTIONS
TREATING INSIDE OF BOLTED TANKS
NATURAL GASOLINE PLANTS AND REFINERIES
(Gasoline, Steam and Acid Lines)
GAS DISTRIBUTION SYSTEMS
(Meter Installations)

RECTORSEAL, in this short period, has been found so far superior to all conventional thread fillers that many oil companies have made it their standard for treating threaded connections against leaks. You, too, can have the advantages of this revolutionary discovery. Buy it through your supply store, or write direct for smear sample.

Made by the makers of
RECTORHEAD
Successor to the Bradenhead

RECTOR WELL EQUIPMENT CO., INC.
HEADQUARTERS: Fort Worth, Texas. BRANCHES: Houston, Wichita Falls, Midland, Corpus Christi, Los Angeles, Tulsa, Shreveport, Casper.

Tilley, Gulf Oil Corporation, vice chairman; Oscar Lynch, Humble Oil and Refining Company; Jack Parker, Transportation Equipment Company; T. G. Price, Shell Petroleum Corporation; Frank Nolan, The Texas Company; Alex Muncie, Pure Oil Company; Lonnie Smith, Sun Oil Company.

Preparing for Annual Meeting A.P.I.

Plans are being made for the 19th Annual Meeting of the American Petroleum Institute, scheduled for November 14 to 18 in the Stevens Hotel at Chicago, Illinois. Announcement of the preliminary program will be made shortly, at which time the advance list of speakers and subjects will be given.

Outstanding speakers will appear on the program for the two general sessions to be held Wednesday and Thursday afternoon, November 16 and 17. As usual, the first two days of the meeting, Monday and Tuesday, November 14 and 15, will be devoted to separate sessions of the Institute's many committees. Group sessions of the Divisions of Production and of Refining will be held Thursday morning, and Friday morning and afternoon.

The first meeting of the Institute's Board of Directors is scheduled for Tuesday afternoon, November 15. The Board of Councillors will meet Wednesday morning, November 16, to nominate directors, who will be elected at the Wednesday afternoon general session. The annual banquet will be held Thursday night in the Grand Ball Room.

Raleigh Hortenstine New Wyatt President

RALEIGH HORTENSTINE

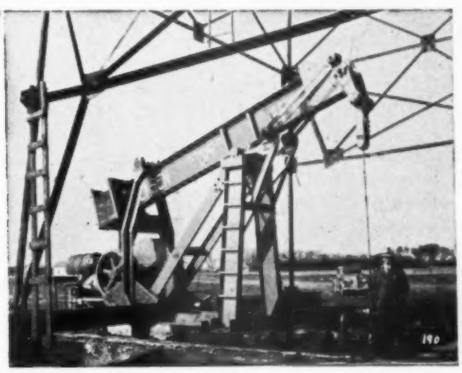
Wyatt Metal and Boiler Works, Houston and Dallas, Texas, announces the election of Raleigh Hortenstine as president following the death of W. J. Wyatt.

Since 1923 Hortenstine has been vice-president and general manager and a director of the company. Prior to his joining Wyatt Metal and Boiler Works he gained much experience in the manufacturing and construction business, beginning with the Penn Bridge Company as designing and construction engineer, during which he was in Pennsylvania, Washington, Louisiana, and Texas. For a time he served the Virginia Bridge and Iron Company as contracting engineer in charge of work in the Southwest and as plant manager at Memphis, Tennessee. He came to the Wyatt organization in an executive capacity in 1923.

Born in Washington County, Virginia, Hortenstine was graduated from Virginia Polytechnic Institute with the degree of bachelor of science in civil engineering, and did a year's graduate work in the College of Civil Engineering at Cornell University. He is a member of the American Society of Civil Engineers.

Dependable Pumping

Here, and in other countries, we want producers to feel that wells do better when JENSEN pumping equipment is used. We have worked to that end exclusively for 19 years.



JENSEN BROTHERS MANUFACTURING CO.

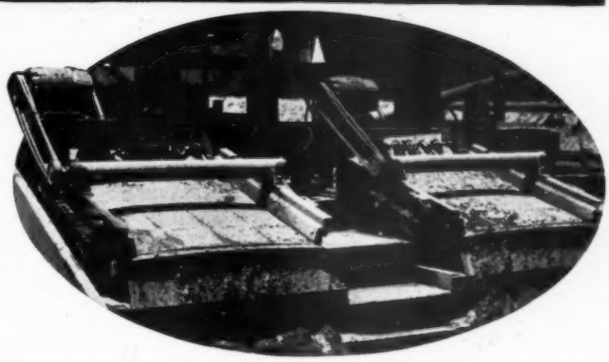
..... Coffeyville, Kansas

Our Rod Line Jacks and our Pumping Units are the world's finest when you consider their low installation costs. May we furnish information based on your problems?

EXPORT OFFICE...136 LIBERTY STREET • NEW YORK, N. Y.

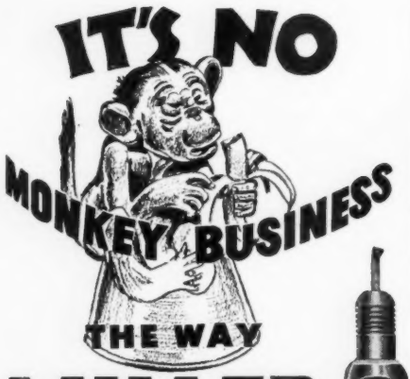
LINK-BELT MUD SCREENS
Quickly Save their Cost

● This Link-Belt dual vibrating screen hook-up is taking shale and other abrasive materials out of drilling mud. Besides keeping destructive materials out of contact with pump parts, thus vastly reducing pump maintenance, a valuable saving in the cost of mud alone is made. For the most efficient, dependable, economical method of reconditioning rotary mud—specify Link-Belt screens. 7541



LINK-BELT COMPANY, Philadelphia, Houston, Tulsa, Dallas, Los Angeles, Indianapolis, Chicago, New York. Distributors in all fields.

LINK-BELT *Vibrating* SCREEN



MILLER
Cleans Out!

The powerful suction action of the MILLER Sand Pump cleans-out quickly at small cost the sand and sediment that holds back production.

The MILLER is made in diameters of 2½, 3, 3½, 4, 4¼, 5, 5½, 7 and 9 inches and lengths of 20, 25 and 30 feet. 5 32-inch wall thickness in REGULAR Type, ¼-inch wall tubes HEAVY Type Sand Pumps.

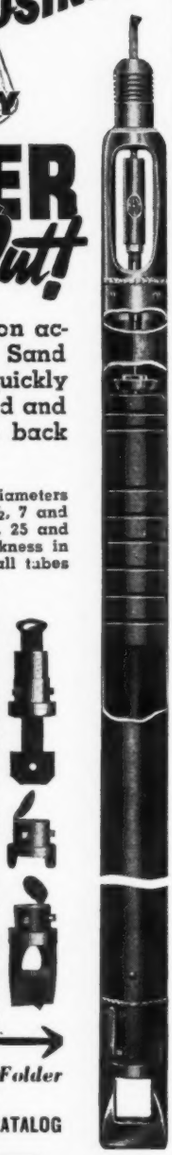
INTERCHANGEABLE BOTTOMS
To Meet Every Condition

● BAILER BOTTOM
With the Bailer Bottom installed the MILLER is quickly changed to a Bailer giving you a combination of either Bailer or a Sand Pump in one tool.

● SAND BOTTOM
Used when tools are run and when well is shot to quickly remove loose material.

● STAR BOTTOM
Used for cutting the sand loose.

● CHISEL BOTTOM
(In Pump)
With this bottom tightly packed sand can be easily broken in small pieces so it can be picked up in the pump.



Write for Descriptive Folder and Price List

See Page 1445 COMPOSITE CATALOG

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MILLER
Sand Pump Co.

General Offices and Shop, Box 4516
OKLAHOMA CITY, OKLA., U. S. A.

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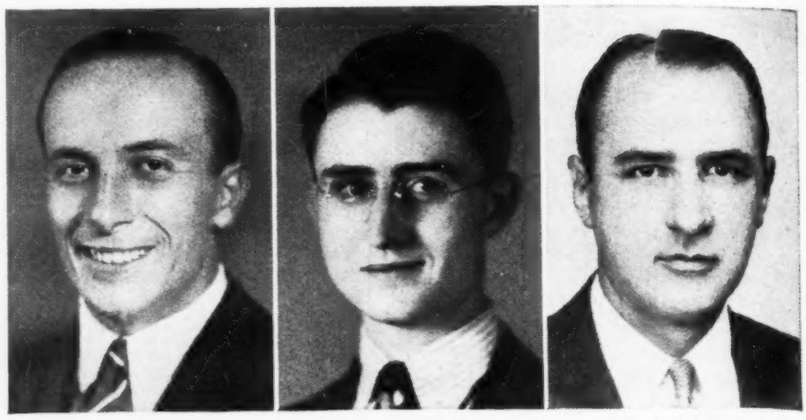
SAPULPA, OKLA. and KILGORE, TEX.

FOR SALE BY SUPPLY STORES EVERYWHERE

Clark Brothers Company Announces New Technical Service Division



F. W. LAVERTY T. C. WEBB F. J. JOBST

J. B. O'Connor, vice-president of Clark Brothers Company, Olean, New York, has announced the formation of a new department of his company to be called the Technical Service Division. This department will correlate the field and shop engineering of the company, and have charge of all process design problems, making a study of the various oil production and refinery problems so that the equipment manufactured by Clark Brothers Company will be designed to suit the customer's process.

The department will be in charge of F. W. Laverty, who has been associated with Clark Brothers Company for 12 years, and is considered one of the outstanding men in the field of thermodynamics. Laverty will have associated with him in his Olean office Dr. T. J. Chrzan and W. D. Bathurst.

At the company's Tulsa office the department will be under T. C. Webb, who formerly was associated with the Bureau of Mines, and has also had considerable experience in the design of natural gasoline recovery plants.

F. J. Jobst will represent this department in the company's New York office. H. J. Turner, formerly with the C. F. Braun Corporation, a new addition to Clark Brothers staff, will be located at Dallas.

Union Wire Rope Opens Houston Branch

Union Wire Rope Corporation, Kansas City, Missouri, has opened a branch warehouse in Houston, Texas. The warehouse, at 5805 Navigation Boulevard, has been stocked with a complete line of wire ropes. It will serve distributors and their customers in the Gulf Coast area of Texas, Louisiana, Mississippi, and Alabama, as well as in Mexico and South America.

H. E. Frye has been appointed Gulf Coast manager of the corporation, and has been transferred from Portland, Oregon, to Houston. Al Andusky has been transferred from the Kansas City plant to Houston, to become manager of the warehouse.

The present warehouse is a temporary location pending construction of a completely new building on a site already selected. The distributor of Union Wire Lines in the Houston area is the Plowden Supply Company, 2300 Navigation Boulevard.

Part of the shipments from Kansas City have been routed via barge lines down the Missouri and Mississippi rivers to the Gulf.

Increase in International Motor Truck and Tractor Production

A program of increased tractor and motor truck production, which, over a period of several weeks, will return several thousand men to jobs at tractor and motor truck plants in Chicago, Illinois, Milwaukee, Wisconsin, Fort Wayne, Indiana, Springfield, Ohio, and Rock Island, Illinois, was recently announced by the International Harvester Company.

Estimates are that about 6500 men will return to work at the company's automotive plants during the next several weeks. Workers will be returned to their jobs according to seniority of service agreements with employees, in effect at each of the three plants.

Employment will also be stimulated in the company's West Pullman plant in Chicago, which makes auxiliary parts, as a result of the re-employment in the automotive plants.

The Harvester company's increased truck and tractor program has been made possible as a result of improvement in tractor and motor truck sales in recent weeks.

After a long, tiring drive it's surely a happy sight to see an Affiliated National Hotel.

Yes, it's the best part of the trip to be able to rest and relax in a hotel that emphasizes courtesy and service as do the thirty-three

Affiliated **NATIONAL HOTELS**

ALABAMA
THOMAS JEFFERSON ..... Birmingham

ILLINOIS
HOTEL FAUST ..... Rockford

LOUISIANA
JUNG HOTEL ..... New Orleans
HOTEL DESOTO ..... New Orleans

MISSISSIPPI
HOTEL LAMAR ..... Meridian
HOTEL RIVIERA ..... Biloxi

NEBRASKA
HOTEL PAXTON ..... Omaha

NEW MEXICO
HOTEL CLOVIS ..... Clovis

OKLAHOMA
OKLAHOMA BILTMORE ..... Oklahoma City
HOTEL HUBER ..... Muskogee
HOTEL BELMONT ..... Okmulgee
HOTEL SAPULPA ..... Sapulpa
HOTEL ALDRIDGE ..... Wewoka

TEXAS
STEPHEN F. AUSTIN ..... Austin
HOTEL SETTLES ..... Big Spring
HOTEL BROWNWOOD ..... Brownwood
HOTEL SOUTHERN ..... Brownwood
HOTEL LAGUNA ..... Cisco
HOTEL CLIFF TOWERS ..... Dallas
HOTEL DONNA ..... Donna
HOTEL CORTEZ ..... El Paso
HOTEL TEXAS ..... Fort Worth
HOTEL BUCCANEER ..... Galveston
HOTEL JEAN LAFITTE ..... Galveston
CORONADO COURTS ..... Galveston
MIRAMAR COURT ..... Galveston
HOTEL CAVALIER ..... Galveston
HOTEL LUBBOCK ..... Lubbock
HOTEL FALLS ..... Marlin
HOTEL GHOLSON ..... Ranger
HOTEL CACTUS ..... San Angelo
ANGELES COURT ..... San Antonio

VIRGINIA
HOTEL MOUNTAIN LAKE ..... Mt. Lake

AFFILIATED
NATIONAL HOTELS
HOST TO THE NATION
H-8-232

Langley to Represent Manufacturers

About October 20, 1938, W. C. Langley will return to Trinidad and South America, to represent American Iron and Machine Works Company, Byron Jackson Company, Elliott Core Drilling Company, Lane-Wells Company, and Security Engineering Company, Inc., in Trinidad, Venezuela, and Colombia.

W. C. LANGLEY

Langley, for the last ten years, has been connected with the Standard Oil Company of Venezuela, on standardization and materials work both in Trinidad and Venezuela. Prior to that time he was for three years engaged in actual field work in Southwest Africa for the Sinclair interests.

After November, 1938, Langley will make his headquarters in Port of Spain, Trinidad.

Geo. E. Justice Joins Homco Staff

Geo. E. Justice has joined the Cutting and Fishing Tool Division of Houston Oil Field Material Company, in charge of sales and engineering, and will work out of the Houston headquarters. He formerly was district manager for Hinderliter Tool Company in Oklahoma and Texas and for the last five years has been in Houston.

GEO. E. JUSTICE

HOT or COLD

This LINE SCALE is always ACCURATE

..because weather cannot affect it, neither can leaky connections as no fluid is used. Super-sensitive but extremely rugged.

Trade Mark Reg. U. S. Pat. Off.

The Line Scale is easily installed, and once properly adjusted gives uninterrupted service. Instructions for operating:

"JUST READ THE DIAL".

Packer Special	*100,000 lbs.,*	*$195.00*
Conrad	*180,000 lbs.,*	*260.00*
Greenhead	*360,000 lbs.,*	*300.00*
Super	*500,000 lbs.,*	*320.00*

F.O.B. Oklahoma City

- DRILLING SCALES
- AUTOMATIC RECORDERS
- DYNAMOMETERS

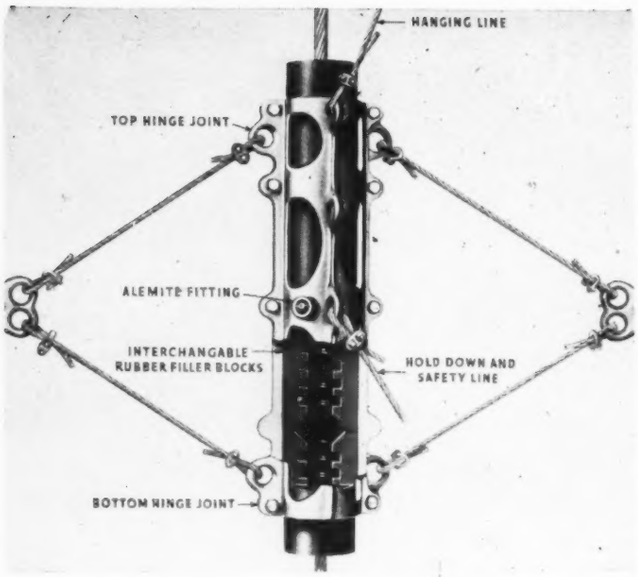
Available at Your Supply Store

Line Scale Co. Inc

Phone 2-1765

907 E. East 29th P. O. Box 4139

OKLAHOMA CITY, OKLA.



PATTERSON-BALLAGH

Wire Line Guide

Eliminates Whip and "Traveling Wave"

Try One on Your Well and Note the Saving

PATTERSON-BALLAGH CORPORATION

Plant and General Offices: 1900 E. 65th Street, Los Angeles, California
Mid-Continent Office: 1507 Maury Street, Houston, Texas
Export Office: 39 Cortlandt Street, New York City

WILLIAMS BROTHERS CORPORATION

CHICAGO

TULSA

HOUSTON

GENERAL CONTRACTORS

PIPE LINES

Oil . . Gas . . Gasoline . . Water

CONSTRUCTION AND RECONDITIONING

Trade Personals

H. JOHN EASTMAN, president of the Eastman Oil Well Survey Company, Dallas, Texas, returned to the United States recently from his annual European trip. Eastman has an oil-well surveying and controlled directional drilling business in Roumania, headquarters being at Ploesti. His Roumanian business is in charge of J. E. Treacy.

Eastman reports conditions are considerably improved in Roumania and that if war is averted they should have a good year. While abroad, Eastman called on the British oil companies in London as well as the Royal Dutch Shell group at The Hague. He also visited Germany, Austria, Hungary, and Czechoslovakia.

C. N. KIRKPATRICK, secretary and sales manager of Landis Machine Company, Inc., Waynesboro, Pennsylvania, sailed October 8th to visit the company's representatives in England and on the Continent.

ALLEN S. HICKS of Hydril Company, Los Angeles, California, sailed October 5th from New York for London, England, enroute to the oilfields of Europe, Asia, and the Netherlands East Indies.

J. C. CONRAD, president of the Line Scale Company, Oklahoma City, Oklahoma, has returned from a trip to Illinois and Kentucky. He was accompanied by P. Z. Conrad, who recently was appointed to service the Illinois-Kentucky area for the company. Conrad was transferred from the West Texas area where he has had headquarters at Odessa.

FRANK I. BROWN, New York, foreign representative for several equipment companies, sailed October 7th, from New York on a business trip to South America. He plans to spend some time in the oilfields of Colombia.

J. R. FUNK, service engineer in Oklahoma and Texas for the Landis Machine Company, Waynesboro, Pennsylvania, left Miami, Florida, recently via Pan American Airways for a trip through South America. Funk will service Landis die heads and Landis thread cutting machines in the oil fields, as well as in the industrial shops throughout South America. His work in Oklahoma and Texas has been taken over by Wm. B. Baker.

T. W. CROSBY has been appointed manager of Oklahoma, Kansas, and Texas district of the McGill Manufacturing Company, Valparaiso, Indiana, making his headquarters at 909 Tulsa Loan Building, Tulsa, Oklahoma. Formerly he was with Wheatley Brothers and the Graver Corporation.

FRED E. COOPER, president of the Fred E. Cooper Company, Tulsa, Oklahoma, recently passed the tests necessary to qualify as a first-class pilot. In celebration of the event his friends in the aerial fraternity gave him a party at the Shamrock Inn, during the course of which his "wings" were presented.

RUSSELL SMITH, former resident salesman in Kansas for W. C. Norris, Manufacturer, Tulsa, Oklahoma, has been transferred as branch manager to St. Elmo, Illinois, where the company has opened a new store. Also transferred to the new store are Jack Whitten from the plant and H. J. Osborne, Jr., from Odessa, Texas.

AVERY PHILLIS has been appointed district manager of the midwestern sales territory for Beaver Pipe Tools, Inc., Warren, Ohio, having his headquarters in Chicago, Illinois. He succeeds W. S. Andrews, who has resigned to accept a position with the Pittsburgh Equitable Meter Company.

UNCONDITIONAL GUARANTEE
If this Housing ever Breaks or Distorts we will replace it Free.
COPR. 1937
THE RIDGE TOOL CO.
TRADE RIDGID

Quit Wasting Time and Money on Pipe Wrench Repairs

The Guaranteed RIDGID Housing keeps this wrench on the job . . . doing better work

Millions of RIDGID wrenches in use under that housing guarantee — and the users will tell you they *stay on the job!* That proves how RIDGIDs help you avoid the nuisance of repairs, let you get along with fewer wrenches, save you money.

You enjoy using the safe all-alloy RIDGID with its replaceable chrome molybdenum jaws, its adjusting nut that never binds even in the 60" size, its powerful I-beam comfort-grip handle.

It's a tool that inspires workmanlike pride and care. For economy and efficiency, buy RIDGIDs — at your Supply House.

THE RIDGE TOOL CO., ELYRIA, OHIO

New All-Steel and Malleable Alloy RIDGID Threader

Better, easier, faster pipe threading, threads 4 sizes of pipe with 1 set of chaser dies — choice of two speedy new automatic workholders. Write for new folder.

RIDGID PIPE TOOLS

Naramore Goes With A.I.M.E.

CHESTER NARAMORE

The board of directors of the American Institute of Mining and Metallurgical Engineers has appointed Chester Naramore assistant secretary and he automatically becomes executive secretary of the Petroleum Division. He will devote a large part of his time to travel in the oil fields and his work is expected to make the Institute increasingly effective in serving the petroleum group.

Naramore has been an independent consulting engineer.

Texas Mid-Continent Oil and Gas Association Plans Big Meeting

An imposing list of speakers and an outstanding program of entertainment are announced by President Charles P. McGaha of the Texas Mid-Continent Oil and Gas Association for its annual meeting October 27 and 28, at San Antonio, Texas.

With the San Antonio convention committee headed by Al Buchanan planning for the largest and most enjoyable meeting in association history, the business sessions will feature several prominent speakers. Heading the list is Governor-Nominate W. Lee O'Daniel of Texas who will address the oilmen at the Thursday afternoon session, October 27. A reception honoring the next governor of the nation's leading oil state will be held immediately afterward to give him opportunity to become better acquainted with Texas and Mid-Continent oilmen.

CHAS. P. McGAHA

President McGaha, in the president's address Thursday morning, will present results of a study made by the association of oil and its place in the economic life of the state, an address due to be of keen interest and great importance to all the oilmen of Texas. George H. Sheppard, state comptroller of public accounts, will speak at the special tax meeting Friday afternoon, October 28, on the gross production tax. Reports on the tax situation will be made to the general session Thursday, as will others on theft prevention and social security. A nationally-known speaker, whose name will be announced later, will feature the Friday business session.

Entertainment will include the golf tournament, in which more than 250 oilmen are due to compete for the W. B. Hamilton Trophy as well as numerous other prizes. San Antonio's best golf courses will be opened to the oil visitors not only for the tourney Friday afternoon, but also for the week-end. A golf tournament for the ladies also is being planned. A luncheon, bridge tea, and tour of the old missions and points of interest in beautiful old San Antonio are other features of entertainment for the ladies attending.

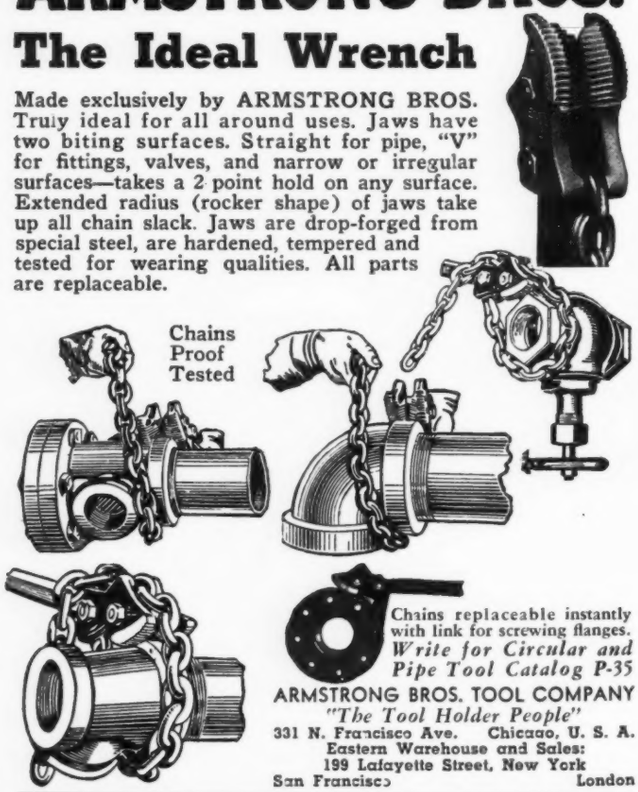
The convention proper will close with the annual banquet Friday night, October 28, in the Rainbow Terrace of the St. Anthony Hotel. Music will be provided by Joe Reichman's orchestra and by a special rhumba band, and a floor show of big-time talent is being arranged. Post-convention entertainment for the Saturday and Sunday following is already being planned by the San Antonio oilmen, with a number of small parties, visits to the missions, to Randolph Field, the West Point of the Air, to Fort Sam Houston, and other places of interest in and near the Alamo City.

Look for the *Arm-and-Hammer*

ARMSTRONG BROS.

The Ideal Wrench

Made exclusively by ARMSTRONG BROS. Truly ideal for all around uses. Jaws have two biting surfaces. Straight for pipe, "V" for fittings, valves, and narrow or irregular surfaces—takes a 2 point hold on any surface. Extended radius (rocker shape) of jaws take up all chain slack. Jaws are drop-forged from special steel, are hardened, tempered and tested for wearing qualities. All parts are replaceable.



Chains replaceable instantly with link for screwing flanges.

Write for Circular and Pipe Tool Catalog P-35

ARMSTRONG BROS. TOOL COMPANY

"The Tool Holder People"

331 N. Francisco Ave. Chicago, U. S. A.

Eastern Warehouse and Sales:
199 Lafayette Street, New York

San Francisco London

"ON LOCATION"

AND GIVING A SMOOTH PERFORMANCE

This Fulton Low Pressure Regulator is at work on the gas fuel line of a pump drawing oil from a deep well in Oklahoma. It might be in any place where pumping is done and pressure needs to be regulated. Chaplin-Fulton devices for controlling pressures of oil and other liquids, gas, air, or steam have been standard for over fifty years . . . Ask for catalog.

THE CHAPLIN-FULTON MFG. COMPANY, PITTSBURGH, PA.

BJ Opens Pittsburgh Branch

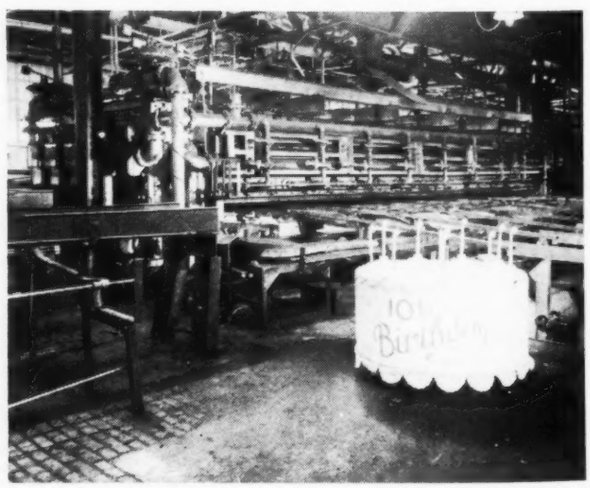
MURRAY RUSSELL

Byron Jackson Company has established a new Pump Division branch office at 703 Gulf Building, Pittsburgh, Pennsylavania. with Murray Russell in charge. The new branch, situated as it is in the heavy industrial area of western Pennsylvania, will enable the company to render a broader and faster service to pump customers in that territory.

Russell joined the Pump Division of Byron Jackson Company nearly ten years ago in Detroit, where he handled many large installations of pumps of diverse types. He was later transferred to the Bethlehem factory, and from there to the Byron Jackson office in New York.

Jones Celebrates Tenth Anniversary of Introduction of Full Normalizing

Technical, manufacturing, and engineering staffs of The S. M. Jones Company were recently astounded when a big four-foot birthday cake with ten candles on it was delivered to the full normalizing furnace in their plant at Toledo. The occasion was the tenth anniversary of the introduction of full normalizing to the sucker rod industry. P. C. Jones, president, took this unusual method to remind the boys of this event, which had its beginning in Smackover, Arkansas, in 1927, where Jones engineers were studying the problem of ring-worm corrosion and subsequently developed fully normalized sucker rods to overcome this difficulty.



Mail Your Subscription Now

Walter Ruska and Company Open New Plant

Walter Ruska and Company, Inc., Houston, Texas, held open house at their new laboratory and plant at 2332 Bellaire Boulevard, September 17.

The company was organized February, 1935, by Ruska, who is now its president and general manager. After having

been graduated from a German college and working as an engineer for such famous German industrial concerns as Siemens and Halske, and Askania, he came to America and worked for the Humble Oil and Refining Company in charge of their research shop.

The new plant is of modernistic design and constructed of hollow tile and concrete. Ample space is provided for the various departments and the plant is well lighted. The employees are favored with attractive quarters and large, clean washrooms.

The plant is equipped with modern machinery to meet all needs of instrument manufacture, all necessary tools for precision work, and measuring equipment for testing and adjusting precision instruments are available. Complete sets of metric threading tools, tools for special threads found in most instruments, cutters for metric involute and cycloid (clock) gears, and pinions are among the tool equipment. Machine engraving and graduating are also done.

J. Fletcher Farrell Passes Away

J. Fletcher Farrell, vice-president, treasurer, and a director of Consolidated Oil Corporation, died at his home in Bronxville, New York, September 25. He had been associated with the company since April, 1916, and in August of that year was elected vice-president and treasurer of Sinclair Oil and Refining Company.

Farrell began his business career with the Paris, Missouri, Savings Bank, of which his father was president. He was engaged in banking until he joined H. F. Sinclair.

He was assistant treasurer of the State of Missouri in 1901. Later he became a representative of Third National Bank of St. Louis and subsequently was elected one of its assistant cashiers. In 1910 he was elected vice-president and director of Fort Dearborn National Bank of Chicago and remained there until his connection with Sinclair Oil and Refining Company as vice-president and treasurer. In 1930, when the merger of Sinclair Consolidated Oil Corporation and Prairie Oil and Gas Company brought formation of the Consolidated Oil Corporation he became a director of the latter.

He also was a vice-president and director of the Mexican Sinclair Petroleum Corporation, Sinclair Navigation Company, Pierce Oil Company, S.A., and Sinclair Cuba Oil Company.

Used all over the World
The B-M-W
Admore Liner Barrel

is now used in most of the well-known oil fields, and for substantial reasons:

INSTALLATION AND REPAIRS—Can be installed without pulling tubing . . . Simply run it on the rods, and it is seated in the top of the standard working barrel, or in a special seating nipple that may be provided. When repairs are necessary the entire pump is pulled with the rods.

OPERATION—The plunger is stationary while the outside tube reciprocates, preventing accumulation of sand. Impossible for sand to settle on the cups.

IN SHALLOW WELLS—In shallow wells the Admore is a very efficient and economical pump, and can be used with Tex Type Plunger Fitting, 8-Cup Plunger Fitting, or Repack Type Plunger Fitting.

IN DEEP WELLS—In deep wells, to 6500 ft., there is much less trouble with sucker rods than when large plunger pumps or standard working barrels are used. This is due to the smaller plunger diameter. Also, with reduced rod stretch, the stroke is more effective, giving maximum capacity.

Complete Data on Request.
See our advertisement in the "Composite Catalog"

YOU CAN BUY ADMORE LINER BARRELS
. . also other B-M-W Products, at supply stores, including:
● TEX TYPE Plunger Fittings and Valves; ● ADMORE Insert Pump Anchors; ● NEILSON Tools (Safety Sucker Rod Hooks, Tubing Hooks, Rod Elevators, Sucker Rod Sockets, etc.); ● BALLS and SEATS (made for every pumping service); and ● COLLINS Belt Clamps.

BRADFORD MOTOR WORKS INC.
OIL WELL SUPPLIES
BRADFORD, PA. — TULSA, OKLA.

Buckeye
Service Ditcher

. . . . JUST RIGHT
for DITCH 15" to 24" WIDE
MODEL 12

Some ditching looks easy — until you start. Or it may look plenty tough. But whether stony soil, restricted right of way, heavy time penalties in the contract, exactness required, or any of a dozen other difficulties confront you, a Buckeye Model 12 will see the job through on schedule.

It digs trench 15" to 24" wide to 5½' deep, at speeds ranging from 22" to 156" per minute. An additional sprocket gives 28' per minute. No soil short of solid rock can stop it. Complete facts are yours for the asking.

BID THE Buckeye WAY
ask for our operation data before you bid

THE BUCKEYE TRACTION DITCHER CO.
FINDLAY, OHIO, U. S. A.

Here...
Oakite Cleaning
REMOVED
sludge from Diesel crankcases

"TAKES that job right out of the nuisance class" say superintendents who use the newly developed Oakite method for cleaning out Diesel crankcases. No wonder they like it! Workmen need NOT stay inside the dirty crankcases hour after hour, laboriously hand scraping and wiping surfaces! Instead, with this new, different method using Oakite cleaning materials, sludge and other accumulations are swiftly, easily, conveniently removed ... and *economically!* Write today for free helpful information. No obligation.

Manufactured only by
OAKITE PRODUCTS, INC., 48 Thames Street, NEW YORK, N. Y.
Branch Offices and Representatives in all Principal Cities of the U. S.

OAKITE *Certified* CLEANING
MATERIALS & METHODS FOR EVERY CLEANING REQUIREMENT

The New
"HUF M-T-L"
Insert Pump

THE new Huf M-T-L Rod Pump comprises a grooved alloy-iron sectional plunger. The pump is installed and removed with the rods, without pulling tubing.

A number of improved features combine to give the Huf M-T-L Pump a longer service life and very efficient operation. The plunger sections are made from a corrosion-resisting alloy iron, heat-treated for greater resistance to wear; the precision barrel tube is of cold-drawn seamless steel. All pumps are equipped with "Repelex" Stainless Steel Balls and Seats as standard equipment.

Sizes are:
2" x 1½"—2½" x 2"—and 3" x 2½"

Write for free Bulletin 1-A, which gives complete details and prices of the Huf M-T-L Insert Pump.

THE CHAS. N. HOUGH MFG. CO.
Franklin, Pa. Tulsa, Okla.

TRADE LITERATURE

THE AXELSON MANUFACTURING COMPANY, Los Angeles, California, has issued a group of bulletins describing the various types of oilwell pumps of its manufacture. Bulletins also have been issued on pump liners and seats and balls. Any or all of these publications will be sent free upon request.

●

BRODERICK AND BASCOM COMPANY, St. Louis, Missouri, has issued a new edition of its Drillers' Wire Rope Handbook. The book contains comprehensive data on wire rope used in the oil industry. Included is information on jerk lines, core barrel lines, and the many miscellaneous ropes that are used around a well, in addition to the larger items of Yellow Strand rotary drilling cable and Broderick and Bascom cable-tool lines.

●

THE HUGHES TOOL COMPANY, Houston, Texas, is distributing a recent publication of theirs entitled "Rotary Core Drilling." This is a comprehensive treatise on the subject, well illustrated, and officials of the company state copies are available free to those desiring them.

●

OIL WELL SUPPLY COMPANY, Dallas, Texas, has issued Bulletin No. 194, which illustrates and describes the "Oilwell" TC-8 pumping unit, a new addition to the company's line of twin-crank units. Bulletin No. 150-A is also being released. This supersedes Bulletin No. 150 and gives up-to-date information on "Oilwell" drill collars.

●

MILLER SAND PUMP COMPANY, Oklahoma City, Oklahoma, is distributing a price list and descriptive folder on all size Miller Sand Pumps. Copies are available free upon request.

●

REPUBLIC STEEL CORPORATION has issued a new 10-page pamphlet entitled "Facts About Republic Standard Pipe," containing bundling tables, sizes and weights, identification and corrosion information on Republic Standard Pipe, Republic Copper-Bearing Steel Pipe, and Toncan Copper Molybdenum Iron Pipe. This is a "Handy Andy" folder for pipe users and can be obtained by writing Republic Steel Corporation, Cleveland, Ohio. Ask for bulletin Adv. 316.

Kibele Appoints Export Distributor

Kibele Manufacturing Company, Dallas, Texas, announces the appointment of Lucey Export Corporation of 3505 Woolworth Building, New York, as its exclusive export distributor for the complete line of Kibele oilfield products. Chief among these are the tubing catcher, swab, valve-in-head packer, and boiler-feed-pump pistons. Lucey Export Corporation is one of the pioneer companies selling oilfield equipment abroad and has representatives in every principal foreign field.

Mid-Continent Supply Opens Houma, Louisiana, Store

The Mid-Continent Supply Company, having general offices in the Mid-Continent Building, Fort Worth, Texas, has just opened a new store at Houma, Louisiana, with A. E. LeClaire as store manager, under the supervision of their Houston, Texas, office.

The installation of this new branch was supervised by R. O. Moore of Fort Worth, general merchandise manager for the Mid-Continent Supply Company.

Book Reviews

Location of Automotive Diesel Troubles Made Easy. 25-in. by 38-in. chart prepared by Victor W. Page, published by Norman W. Henley Publishing Company, 2 West 45th Street, New York, N. Y. 1938. Price, 50 cents. (Special price in quantities.)

This enlarged wall chart shows sectional views of a Diesel engine and its parts and presents in convenient summarized form the common derangements that interfere with efficient operation, their symptoms, effects, and repair procedure.

* * *

The Condensed Library of Engineering, edited by Charles E. Lucke, Columbia University, New York. 16 pp., 1938.

This pamphlet consists of lists of fundamental textbooks pertaining to various phases of mathematics, physics, chemistry, general engineering, mining and metallurgical engineering, civil engineering, mechanical engineering, electrical engineering, chemical engineering, and industrial engineering.

* * *

National Fire Codes for Flammable Liquids and Gases, published by National Fire Protection Association, 60 Batterymarch St., Boston, Mass. 360 pp. 1938. Price, $1.50.

This volume includes specified and recommended practice for storage, transportation, and use of all flammable fluids. The larger part of the book deals with petroleum and refined products. An effort has been made to specify measures that will provide safety but will not entail prohibitive expense, interfere with established industrial practices, nor cause undue inconvenience.

Clark "Angle" Compressors for Belridge Repressuring Plant

The Continental Oil Company of California has ordered two 300-hp. Clark "Angle" compressors for use in its new repressuring plant being constructed in the Belridge field, about 150 miles northwest of Los Angeles. The order was placed with the Smith Booth Usher Company, of Los Angeles, Pacific Coast agents for Clark Brothers Company.

The units ordered are 3-cylinder, 300-hp. RA32 "Angle" compressors fitted with Type VTHF cylinders of 4⅜ in. diameter, for developing a maximum pressure of 3000 pounds.

John Zink Burners Move New York Office

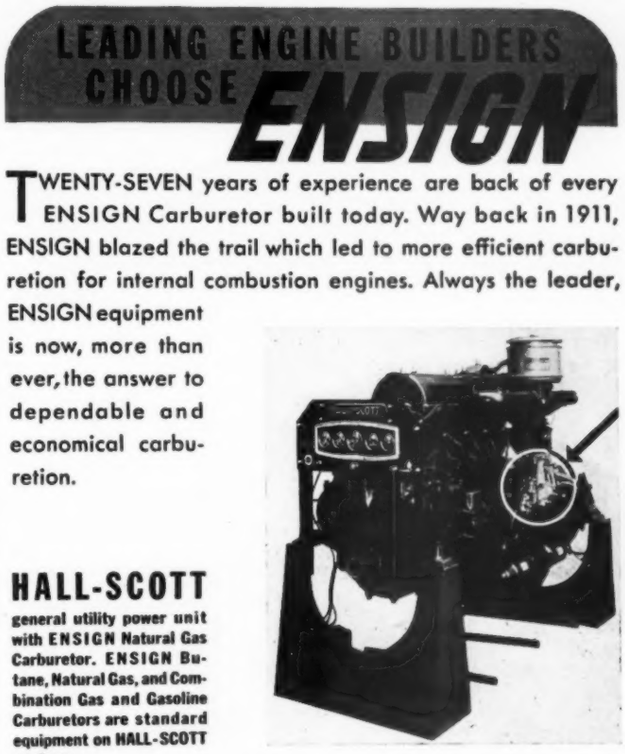
John Zink, owner of John Zink Burners, Tulsa, Oklahoma, announces the removal of the company's New York offices to 342 Madison Avenue, Telephone VAnderbilt 3-1074, New York City. J. Arthur Moore, formerly of the Oilfield Equipment Company, will be in charge of the New York office.

Byron Jackson Transfers Personnel

Lynn Sawyer, formerly in charge of the district office at Fort Worth, Texas, of the Pump Division, Byron Jackson Company, has been made district manager of the New York office.

Ed Upton, formerly connected with the New York and Chicago offices of Byron Jackson Company, assumes charge of the Fort Worth office.

Gotkool
WATER CANS
& COOLERS
GOTT Water Cans are the practical way to keep drinking water cool for long periods, protected from impurities and always handy to the job. Snug fitting large removable top, strongly built to withstand rough usage. GOTT Water Coolers have extra large covers and a handy non-leaking push button faucet. Your Supply Store has them, get one today! . . . . .
GOTT WATER CAN
Made in 1½, 3, 5, and 10 gallon sizes.
GOTT WATER COOLER
H. P. GOTT MFG. CO.
WINFIELD, KANSAS
KEEP PURE DRINKING WATER ALWAYS HANDY


LEADING ENGINE BUILDERS CHOOSE
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INSTALLMENT No. 17

INTERPOLATION. In mathematics, the insertion of terms in a series according to the law of the series, such as, for example, values in a table, is known as interpolation. The method of interpolation generally used is the direct-ratio method. As an example, assume that the following figures appear in a table:

a	b
20	156.8
30	235.2
40	313.6

It is desired to find by interpolation from column "b" a value corresponding to the value of 24 in column "a". The value 24 does not appear in column "a", but it lies between the value of 20 and 30. Dividing the interval between these two numbers into ten equal parts the required value, which we shall call x, will be 156.8 plus 4/10 of the difference between 235.2 and 156.8 (these two numbers are the values in column "b" corresponding to the respective values 30 and 20 in column "a")

$$\text{or: } x = 156.8 + \frac{4}{10}(235.2 - 156.8)$$

$$x = 188.2$$

This method is accurate only when applied to data based on straight-line or linear functions, i.e., data that when plotted on rectangular co-ordinates fall on a straight line. However, if the intervals between variables are relatively small, the error induced by using the direct-ratio method of interpolation in tables based on exponential, logarithmic, and other data will be negligible.

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TEMPERATURE—SPECIFIC GRAVITY MULTIPLIERS ($\frac{22.8}{\sqrt{ST_1}}$ OF WEYMOUTH'S FORMULA)

Sp. gr. of gas (Air = 1)	Flowing temperature, deg. fahr.							
	30	40	50	60	70	80	90	100
0.40	1.629	1.612	1.597	1.581	1.566	1.552	1.537	1.524
0.45	1.536	1.520	1.505	1.491	1.477	1.463	1.450	1.437
0.50	1.457	1.442	1.428	1.414	1.401	1.388	1.375	1.363
0.55	1.389	1.375	1.362	1.348	1.336	1.323	1.311	1.299
0.60	1.330	1.317	1.304	1.291	1.279	1.267	1.255	1.244
0.65	1.278	1.265	1.252	1.240	1.229	1.217	1.206	1.195
0.70	1.231	1.219	1.207	1.195	1.184	1.173	1.162	1.152
0.75	1.190	1.178	1.166	1.155	1.144	1.133	1.123	1.113
0.80	1.152	1.140	1.129	1.118	1.107	1.097	1.087	1.077
0.85	1.117	1.106	1.095	1.085	1.074	1.064	1.055	1.045
0.90	1.086	1.075	1.064	1.054	1.044	1.034	1.025	1.016
0.95	1.057	1.046	1.036	1.026	1.016	1.007	.9976	.9887
1.00	1.030	1.020	1.010	1.000	.9905	.9813	.9724	.9636

Weymouth's formula for flow of gas through high-pressure pipe lines is

$$Q_s = 433.45 \frac{T_s}{P_s}\sqrt{\frac{d^{5\frac{1}{3}}(P_1^2 - P_2^2)}{LST_1}}$$

wherein Q_s = volume of gas, cu. ft. per day, at standard pressure and temperature, P_s and T_s
d = I.D. of pipe, in.
P_1 = initial pressure, lb. per sq. in. abs.
P_2 = terminal pressure, lb. per sq. in. abs.
L = length of line, miles
S = sp. gr. relative to air as unity
T_1 = temperature of gas, deg. fahr. abs.

For convenience this formula may be divided into three factors thus:

$$Q_s = 671\sqrt{P_1^2 - P_2^2} \cdot \sqrt{\frac{d^{5\frac{1}{3}}}{L}} \cdot \frac{22.8}{\sqrt{ST_1}}$$

at standard temperature and pressure of 60 deg. fahr. (520 deg. fahr. abs.) and 14.73 lb. per sq. in. abs. respectively.

BETTER WELDING AT LOWER COST

Costs of Laying Pipe Lines Are Reduced With New Multi-Flame Tips and High-Speed Rod . . . .

Additional economies in the joining of pipe by the Lindeweld Process now are obtainable by using the new Oxweld 6-Flame Tip for making rolling welds—and the new Oxweld 4-Flame Tip for position welds—with the new, high-speed Oxweld No. 32 C.M.S. Steel Welding Rod.

Rolling welds in pipe now can be made 35 to 70 per cent faster than was previously possible with multi-flame welding. Position welds can be made at least 25 per cent faster. Stronger and tougher welds of uniformly high quality can be produced—and savings of 20 per cent or more in oxygen and acetylene consumption can be realized.

Full information about these new products for use with the Lindeweld Process of permanently joining pipe by the oxy-acetylene flame is available in the booklet, "Speeding the Construction of Overland Pipe Lines." A copy will be sent you on request.

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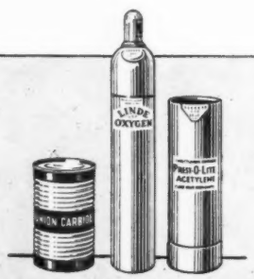

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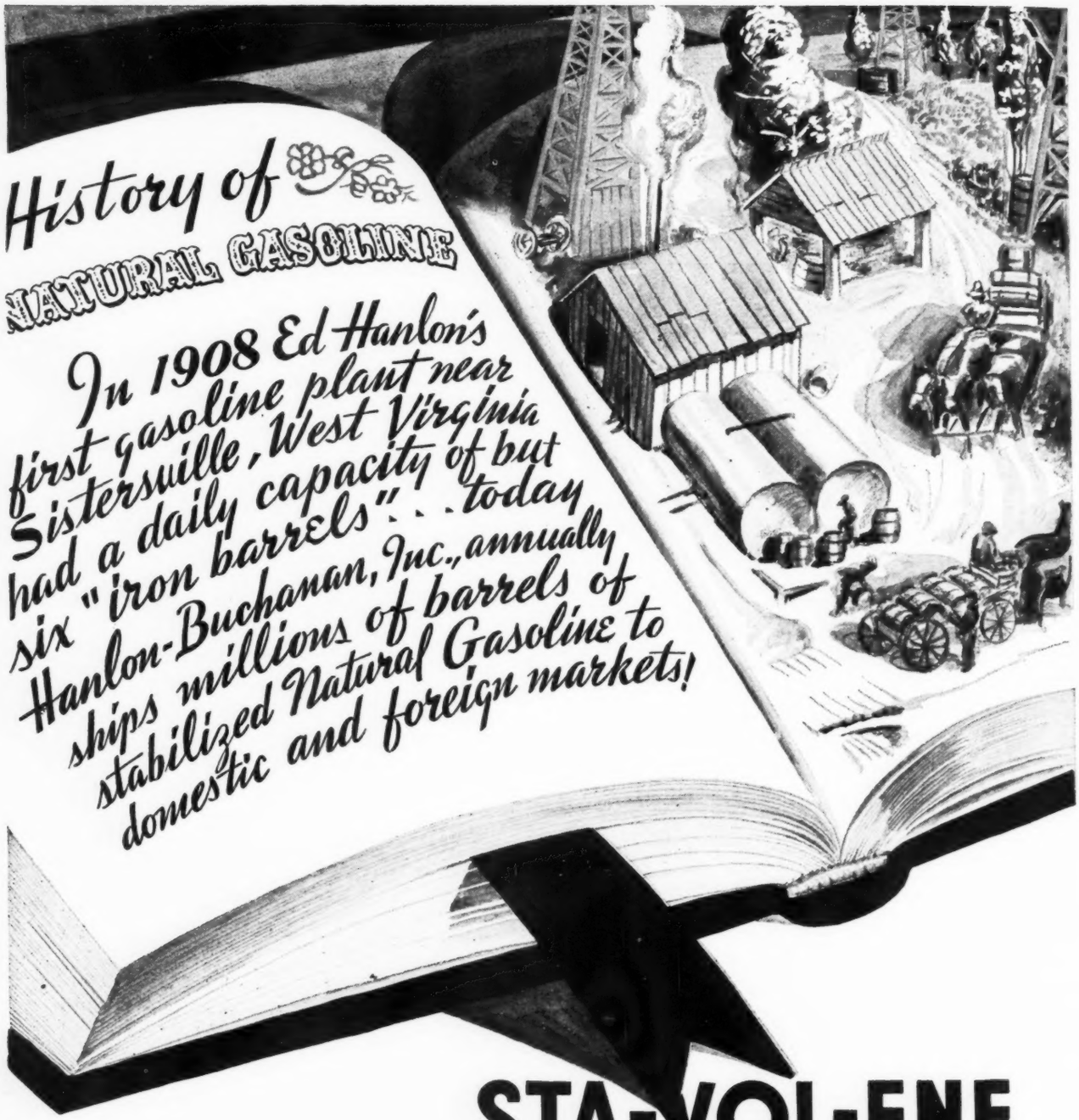
LINDE OXYGEN · PREST-O-LITE ACETYLENE · OXWELD APPARATUS AND SUPPLIES · UNION CARBIDE

VAPORIZATION EQUILIBRIUM CONSTANTS[1] (K-VALUES) OF n-PENTANE

Temperature, deg. fahr.	Pressure, lb. per sq. in. abs.																			
	10	14.7	20	30	40	50	60	70	80	90	100	120	140	160	180	200	250	300	400	500
20	.28	.19	.147	.102	.082	.069	.058	.051	.047	.043	.039	.035	.0 2	.02[illegible]	.027	.02	.022	.020		
40	.43	.29	.226	.157	.125	.105	.089	.079	.073	.067	.062	.054	.048	.045	.042	.039	.034	.031	.027	.025
60	.66	.46	.348	.243	.191	.159	.136	.119	.110	.102	.093	.080	.073	.067	.063	.059	.051	.047	.041	.038
80	.98	.68	.515	.363	.282	.233	.199	.176	.161	.147	.136	.118	.106	.098	.092	.087	.076	.070	.060	.056
100	1.44	1.01	.755	.528	.405	.338	.288	.254	.232	.213	.193	.168	.152	.139	.132	.123	.109	.099	.086	.080
120	2.05	1.42	1.08	.75	.57	.473	.402	.360	.322	.294	.268	.233	.212	.195	.182	.170	.151	.137	.120	.110
140	2.83	1.96	1.47	1.02	.78	.645	.545	.487	.437	.398	.367	.316	.284	.265	.247	.230	.206	.186	.163	.150
160	3.8	2.61	1.96	1.37	1.03	.855	.720	.643	.575	.523	.473	.413	.373	.344	.320	.297	.264	.243	.212	.194
180	5.0	3.45	2.58	1.81	1.37	1.12	.95	.83	.74	.67	.61	.53	.48	.438	.405	.378	.335	.310	.271	.248
200	6.4	4.35	3.33	2.28	1.75	1.43	1.20	1.06	.94	.84	.77	.67	.60	.55	.51	.47	.42	.38	.335	.306
220	8.1	5.55	4.18	2.79	2.18	1.77	1.50	1.30	1.16	1.04	.95	.83	.74	.67	.62	.57	.51	.47	.40	.37
240	9.9	6.75	5.15	3.53	2.68	2.17	1.83	1.59	1.41	1.26	1.16	1.00	.88	.81	.74	.68	.60	.56	.48	.44
260	11.8	8.2	6.15	4.25	3.22	2.59	2.18	1.88	1.67	1.50	1.37	1.18	1.04	.96	.88	.80	.71	.65	.56	.52
280	14.0	9.6	7.15	5.02	3.77	3.05	2.57	2.21	1.96	1.75	1.59	1.37	1.22	1.11	1.02	.93	.82	.75	.65	.59
300	16.1	11.1	8.4	5.8	4.37	3.53	2.95	2.54	2.26	2.04	1.83	1.58	1.39	1.26	1.16	1.06	.93	.85	.74	.67
320	18.2	12.4	9.4	6.5	4.95	3.95	3.35	2.88	2.53	2.28	2.06	1.76	1.54	1.41	1.30	1.18	1.03	.94	.82	.74
340	20.3	13.8	10.4	7.2	5.5	4.4	3.7	3.2	2.8	2 52	2.30	1.94	1.70	1.54	1.43	1.30	1.13	1 03	.90	.81
360	22.2	15.1	11.4	7.8	6.0	4.8	4.1	3.5	3.1	2.75	2.50	2.12	1.85	1.68	1.51	1.41	1.23	1.11	.97	.88
380	24.0	16.3	12.3	8.4	6.5	5.2	4.4	3.8	3.3	2.95	2.70	2.26	2.00	1.80	1.66	1.51	1.32	1.20	1.04	.95
400	26.0	17.5	13.1	9.1	6.9	5.6	4.7	4.1	3.6	3.2	2.90	2.43	2.15	1.93	1.79	1.62	1.41	1.29	1.11	1.01
420	27.5	18.8	14.0	9.7	7.4	5.9	5.0	4.3	3.8	3.4	3.10	2.60	2.30	2.01	1.90	1.73	1.50	1.37	1.19	1.08
440	29.0	20.0	14.9	10.3	7.8	6.3	5.3	4.6	4.1	3.6	3.25	2.76	2.43	2.18	2.0	1.84	1.60	1.44	1.27	1.14
460	31.0	21.2	15.8	11.0	8.3	6.6	5.6	4.8	4.3	3.8	3.45	2.9	2.6	2.3	2.1	1.96	1.70	1.52	1.35	1.21
480	32.5	22.5	16.7	11.6	8.7	7.0	5.9	5.1	4.6	4.0	3.6	3.1	2.7	2.4	2.2	2.1	1.80	1.60	1.43	1.28
500	34.	23.8	17.6	12.2	9.2	7.3	6.3	5.4	4.8	4.2	3.8	3.3	2.9	2.6	2.4	2.2	1.9	1.7	1.5	1.34
520	36.	25.0	18.5	12.9	9.7	7.7	6.6	5.7	5.1	4.4	4.0	3.5	3.0	2.7	2.5	2.3	2.0	1.8	1.6	1.41
540	38.	26.3	19.4	13.5	10.2	8.1	6.9	6.0	5.4	4.6	4.2	3.6	3.2	2.8	2.6	2.4	2.1	1.9	1.7	1.50
560	40.	27.6	20.5	14.2	10.7	8.6	7.2	6.4	5.6	4.9	4.4	3.8	3.4	3.0	2.7	2.5	2.2	2.0	1.8	1.58
580	42.	29.1	21.6	15.0	11.2	9.1	7.6	6.7	5.9	5.2	4.7	4.0	3.5	3.2	2.9	2.7	2.3	2.1	1.9	1.66
600	44.	30.7	22.7	15.8	11.8	9.6	8.0	7.1	6.2	5.5	5.0	4.2	3.7	3.3	3.0	2.8	2.4	2.2	2.0	1.75
620	46.	32.3	23.9	16.7	12.5	10.0	8.5	7.5	6.6	5.8	5.3	4.4	3.9	3.5	3.2	3.0	2.6	2.3	2.1	1.84
640	49.	34.0	25.1	17.6	13.2	10.5	8.9	7.9	7.0	6.1	5.6	4.7	4.1	3.7	3.4	3.1	2.7	2.4	2.2	1.94
660	52.	35.7	26.4	18.6	13.9	11.1	9.4	8.3	7.3	6.4	5.9	5.0	4.4	3.9	3.6	3.3	2.9	2.5	2.3	2.05
680	54.	37.8	27.9	19.6	14.6	11.7	9.9	8.7	7.7	6.8	6.2	5.3	4.6	4.1	3.8	3.5	3.0	2.7	2.4	2.16
700	57.	39.8	29.5	20.6	15.4	12.3	10.4	9.2	8.1	7.2	6.5	5.6	4.8	4.3	4.0	3.7	3.2	2.8	2.5	2.28
720	60.	42.	31.1	21.7	16.2	13.0	11.0	9.7	8.6	7.6	6.8	5.9	5.1	4.5	4.2	3.9	3.3	3.0	2.7	2.40
740	64.	44.	32.8	22.8	17.2	13.7	11.6	10.2	9.0	8.0	7.2	6.2	5.4	4.8	4.4	4.1	3.5	3.2	2.8	2.55
760	67.	46.	34.3	24.1	18.2	14.5	12.2	10.8	9.5	8.4	7.6	6.5	5.7	5.1	4.6	4.3	3.7	3.4	3.0	2.70
780	70.	49.	36.4	25.5	19.2	15.3	12.9	11.4	10.0	8.9	8.0	6.8	6.0	5.4	4.9	4.5	3.9	3.6	3.1	2.85
800	74.	52.	38.2	27.1	20.2	16.1	13.7	12.0	10.6	9.5	8.5	7.2	6.3	5.7	5.2	4.8	4.1	3.8	3.3	3.00

[1]From curve showing equilibrium constants for n-Pentane prepared by George Granger Brown, Ann Arbor, Michigan, by permission.


History of
NATURAL GASOLINE
In 1908 Ed Hanlon's first gasoline plant near Sistersville, West Virginia had a daily capacity of but six "iron barrels"... today Hanlon-Buchanan, Inc., annually ships millions of barrels of stabilized Natural Gasoline to domestic and foreign markets!

STA-VOL-ENE

STABILITY VOLATILITY ENERGY

IT'S A "NATURAL"

Hanlon-Buchanan, Inc

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Cable Address . . . STAVOLENE, Tulsa, U. S. A.

FOREIGN REPRESENTATIVE:
Barks, Williams & Co., Ltd.
4 Lloyd's Ave.
London, England

CONVERSION FACTORS

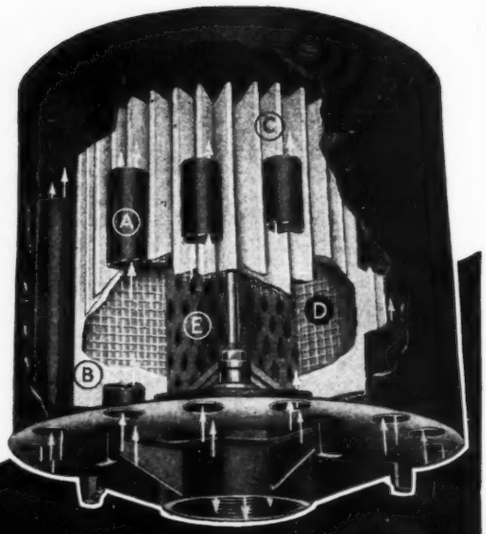
Unit	x Factor =	Unit	x Factor =	Unit
millimeters	0.03937	inches	25.40	millimeters
centimeters	0.3937	inches	2.540	centimeters
meters	3.281	feet	0.3048	meters
kilometers	0.6214	miles	1.6093	kilometers
square centimeters	0.1550	square inches	6.4516	square centimeters
square meters	2.471×10^{-4}	acres	4046.9	square meters
square meters	10.76	square feet	0.092937	square meters
square meters	1.196	square yards	0.83612	square meters
square kilometers	0.3861	square miles	2.590	square kilometers
square kilometers	247.1	acres	4.047×10^{-3}	square kilometers
ares	0.02471	acres	40.47	ares
hectares	2.471	acres	0.4047	hectares
cubic centimeters	6.102×10^{-2}	cubic inches	16.388	cubic centimeters
cubic centimeters	2.642×10^{-4}	gallons U. S.	3785.3	cubic centimeters
cubic centimeters	2.201×10^{-4}	gallons Imperial	4543.6	cubic centimeters
liters	61.02	cubic inches	1.6388×10^{-2}	liters
liters	0.03531	cubic feet	28.32	liters
liters	0.2642	gallons U. S.	3.7853	liters
liters	0.2201	gallons Imperial	4.5436	liters
liters	6.2905×10^{-3}	barrels (42 gal.)	158.97	liters
cubic meters	35.31	cubic feet	0.02832	cubic meters
cubic meters	1.308	cubic yards	0.7645	cubic meters
cubic meters	264.2	gallons	3.785×10^{-3}	cubic meters
cubic meters	6.2905	barrels (42 gal.)	0.15897	cubic meters
Imperial gallons	0.833	U. S. gallons	1.200	Imperial gallons
atmospheres	14.70	pounds per square inch	0.068027	atmospheres
atmospheres	33.90	feet of water	0.0295	atmospheres
atmospheres	29.92	inches of mercury	0.03342	atmospheres
kilograms per square meter	1.422×10^{-3}	pounds per square inch	703.23	kilograms per square meter
kilograms per square meter	0.2048	pounds per square foot	4.883	kilograms per square meter
kilograms per square meter	9.678×10^{-5}	atmospheres	10,332.7	kilograms per square meter
millimeters mercury	1.9268×10^{-2}	pounds per square inch	51.9	millimeters mercury
grams	2.205×10^{-3}	pounds	453.5	grams
kilograms	2.205	pounds	0.4535	kilograms
kilograms	1.102×10^{-3}	tons	907.4	kilograms
metric tons	1.102	tons	0.9074	metric tons
tons of 12° oil	5.7924	barrels of 12° oil	0.17264	tons of 12° oil
tons of 16° oil	5.9538	barrels of 16° oil	0.16796	tons of 16° oil
tons of 20° oil	6.1151	barrels of 20° oil	0.16353	tons of 20° oil
tons of 24° oil	6.2763	barrels of 24° oil	0.15933	tons of 24° oil
tons of 28° oil	6.4383	barrels of 28° oil	0.15532	tons of 28° oil
tons of 32° oil	6.5998	barrels of 32° oil	0.15152	tons of 32° oil
tons of 36° oil	6.7613	barrels of 36° oil	0.14790	tons of 36° oil
tons of 40° oil	6.9223	barrels of 40° oil	0.14446	tons of 40° oil
tons of 44° oil	7.0842	barrels of 44° oil	0.14116	tons of 44° oil
tons of 48° oil	7.2448	barrels of 48° oil	0.13803	tons of 48° oil
gram-calories	3.968×10^{-3}	British thermal units	252.02	gram-calories
kilogram-calories	3.968	British thermal units	0.252	kilogram-calories
kilogram-calories per minute	0.09351	horsepower	10.694	kilogram-calories per minute
grams per cubic centimeter	62.43	pounds per cubic foot	0.016018	grams per cubic centimeter
kilograms per cubic meter	0.06243	pounds per cubic foot	16.018	kilograms per cubic meter
degrees centigrade + 17.8	1.8	degrees fahrenheit —32	5/9	degrees centigrade

← MODEL CPH

for horizontal air transmission lines. Model CP for vertical lines. (1) container; (2) baffle; (3) housing; (4) insert; (5) drain cock.

MODEL DS →

Combination Silencer-filter for internal combustion engine and compressor intake. (A) Rectifying chamber (a series); (B) dry Feltex Filtering Medium; (C) Radial Fin Construction; (D) rigid, galvanized mesh frame; (E) reinforcing tube.



HOW TO Save Money WITH AIR FILTERS

Check over the machinery and processes under your supervision. Are Diesel, gas or gasoline engines, compressors, blowers or electric motors operating without efficient air filters? Do air-powered tools run on unfiltered air? Are air-using processes lacking clean, dry air? Is intricate, expensive machinery unprotected from dust?

AIR FILTERS ARE ECONOMIZERS

In every case, correct air filter installations will reduce operating expenses and maintenance costs. The reasons are simple. Abrasive dust is everywhere. Unless kept out by efficient filters, it scours away cylinder walls, wears out reciprocating parts, clogs delicate machinery. Foreign matter in air transmission lines (pipe scale, rust, dirt, oil and moisture) damages air-using tools; interferes with air-using processes. Facts and figures prove the savings made by high grade air filters. Use them everywhere and watch cost figures drop.

Protectomotor Air Filters 99% Efficient

Tests made by the University of California prove that Protectomotors possess an efficiency only .1% less than absolute. This extraordinary performance is the result of several factors: (1) the patented Radial Fin Construction provides large filtering area in small space, minimum restriction of air flow, (2) the famous Feltex Filtering Medium is tough, long wearing, efficient in stopping the finest dust particles, (3) Protectomotors are built under the closest possible supervision from high quality, selected materials. (Same factors give efficiency to Protectomotor lubricating oil filters.) You can SAVE MONEY using them—write for catalog and data.

Air Filter PROTECTOMOTOR AIR FILTERS *Headquarters*

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